# Lean Six Sigma Yellow Belt

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# QDNA Initiatives

## Drive Customer and WNS Value through proven methodologies

# Lean Six Sigma

## Build Quality Eco System

### About LSS Trainings & Project Certifications

**LSS training & certifications** imbibes quality & continuous improvement culture in the organization through

- Training on LSS tools and techniques and its application to drive business / client impact projects and problem solving.
- Builds a pool of certified GB/BB's resources *(#RFP Requirement)*

**LSS trainings** range from awareness trainings on basic quality tools to GB & BB/MBB training.

- Awareness trainings on Quality are conducted through GLNIT tool and classroom support sessions.
- Class room based GB trainings
- BB training is conducted by external vendors.

**LSS Certifications** are for Kaizen/YB/GB & BB projects. Different methodology can be selected as per project guideline document.

- Project governance and tollgates in the project Portal

**Selected projects are recognized and awarded based on the business Impact**


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# Embarking on Lean Six σ Journey

| Lss Categories | Lean Six σ \| Yellow Belt | Lean Six σ \| Green Belt | Lean Six σ \| Black Belt | Lean Six σ \| Master Black Belt | Lean Six σ \| Champion |
|---|---|---|---|---|---|
| **Band Eligibility** | All Band Levels (Across WNS) | Band B2 + (Across WNS) | Band B1 + (Quality & Project Roles only) | Band C+ (Quality & Project Roles only) | Band D + (Across WNS) |
| **Pre-requisites** | None | Completed Yellow Belt or any Glint based quality training | Green Belt Certified | Black Belt Certified | Prior LSS training |
| **Training Nominations** | Self | Manager | Manager C1 + | Invitation by BPET / Band D | Self \| Invitation |
| **Mandatory Certification Roadmap** | ▪ Attend LSS Training<br>▪ Clear Examination<br>▪ Complete 1 YB Project | ▪ Attend LSS Training<br>▪ Clear LSSGB Examination<br>▪ Complete 1 GB Project (Panel Certification) | ▪ Attend LSS Training *<br>▪ Clear LSSBB Examination<br>▪ Complete 2 BB Project (Panel Certification)<br>▪ Mentor 3 GB Projects<br>▪ Deliver 40Hrs LSS Training | ▪ Attend LSS Training<br>▪ Clear LSSMBB Examination<br>▪ Complete the 1 MBB Project (Panel Certification)<br>▪ Mentor 3 BB Projects<br>▪ Deliver 80Hrs LSS | ▪ Attend LSS Training<br>▪ Drive Six Sigma Culture<br>▪ Deliver 10Hrs Influential Speech (Webinars , Road Shows , Training etc)<br>▪ Lead Champion Reviews (Own Champions Dashboard) |
| **Expected benefits** | ▪ Metric Improvement | ▪ Metric Improvement<br>▪ $50K – 100K worth Biz Impact | ▪ Metric Improvement<br>▪ $100K - 500K worth Biz Impact | ▪ Metric Improvement<br>▪ Greater than $500K worth Savings | ▪ Metric Improvement |
| **Association Partner** | KPMG | Indian Statistical Institute | benchmark six sigma | | |

In Addition to these Kaizen projects can be initiated across all Bands for projects which required basic Quality tools


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# LSS Trainings

| LSS Training | Eligibility | Duration | Mode of Training | Project Certification | Remarks |
|---|---|---|---|---|---|
| GLNIT Based Awareness Trainings<br>7QC tools<br>Process Mapping<br>Basic of LSS<br>Yellow Belt<br>Green Belt | All | As per GLNIT mentioned Timelines | Online GLNIT Training | Kaizen Project | BLSS Training mandatory for Kaizen certification |
| LSS - YB | All | 1 Day | Classroom Based/Online GLINT Training | LSS YB | YB Training mandatory for Kaizen certification |
| LSS - GB | B2 and Above | 3 Days | Classroom Based/Online GLINT Training | LSS GB | DMAIC – 3 Days Training mandatory for GB certification |
| LSS – BB (Proposed) | B1 and above | 2 weeks | Classroom Based | LSS BB | Week 1 – DMAIC Rigor<br><br>Week -2 Advanced Tools |
| Lean Training Module in Lean Agile Catalyst training (LAC*) | All | 2 Hrs of Lean Training required in LAC program | Online | Certification provided by LAC team | |

**LAC program : it's a 2 days training program lead by Agile team. 2 hrs session on Lean tools is conducted as a part of program.*


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# Awards

| Award Category | QNS Category | Award |
|---|---|---|
| Best Black Belt Project | Hard QNS > = $50K | LOC Points equivalent ranging from ~$300 up to ~$500 |
| Green Belt Projects | Hard QNS >= $25K | LOC Points equivalent ranging from ~$100 up to ~$500 |
| Yellow Belt Projects | Hard QNS >= $10K | LOC Points equivalent to ~$50 up to ~$100 |

# Above Award Includes Best projects for the Quarter and Best Project of the Year.


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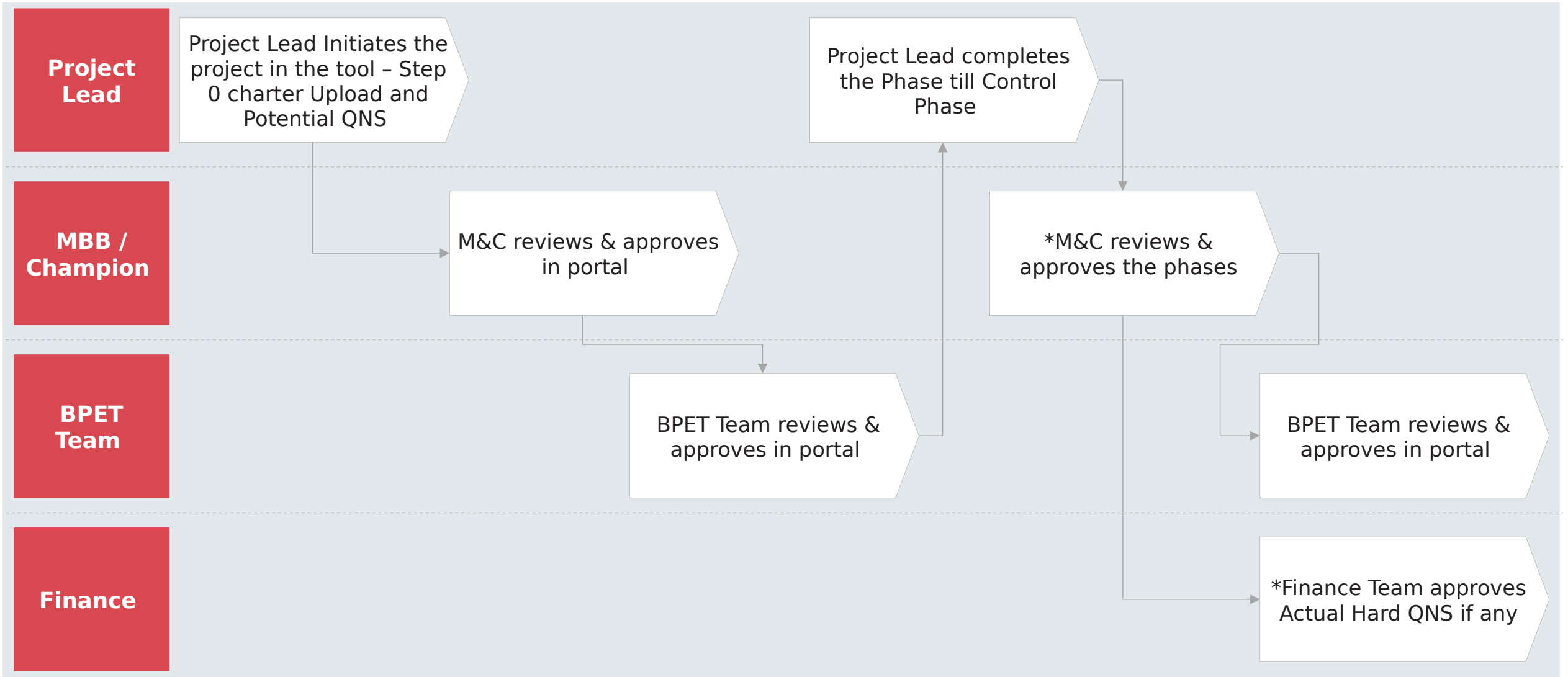
# LSS Project Process Flow (High Level)


Project Lead
MBB / Champion
BPET Team
Finance
Project Lead Initiates the project in the tool – Step 0 charter Upload and Potential QNS
M&C reviews & approves in portal
BPET Team reviews & approves in portal
Project Lead completes the Phase till Control Phase
*M&C reviews & approves the phases
BPET Team reviews & approves in portal
*Finance Team approves Actual Hard QNS if any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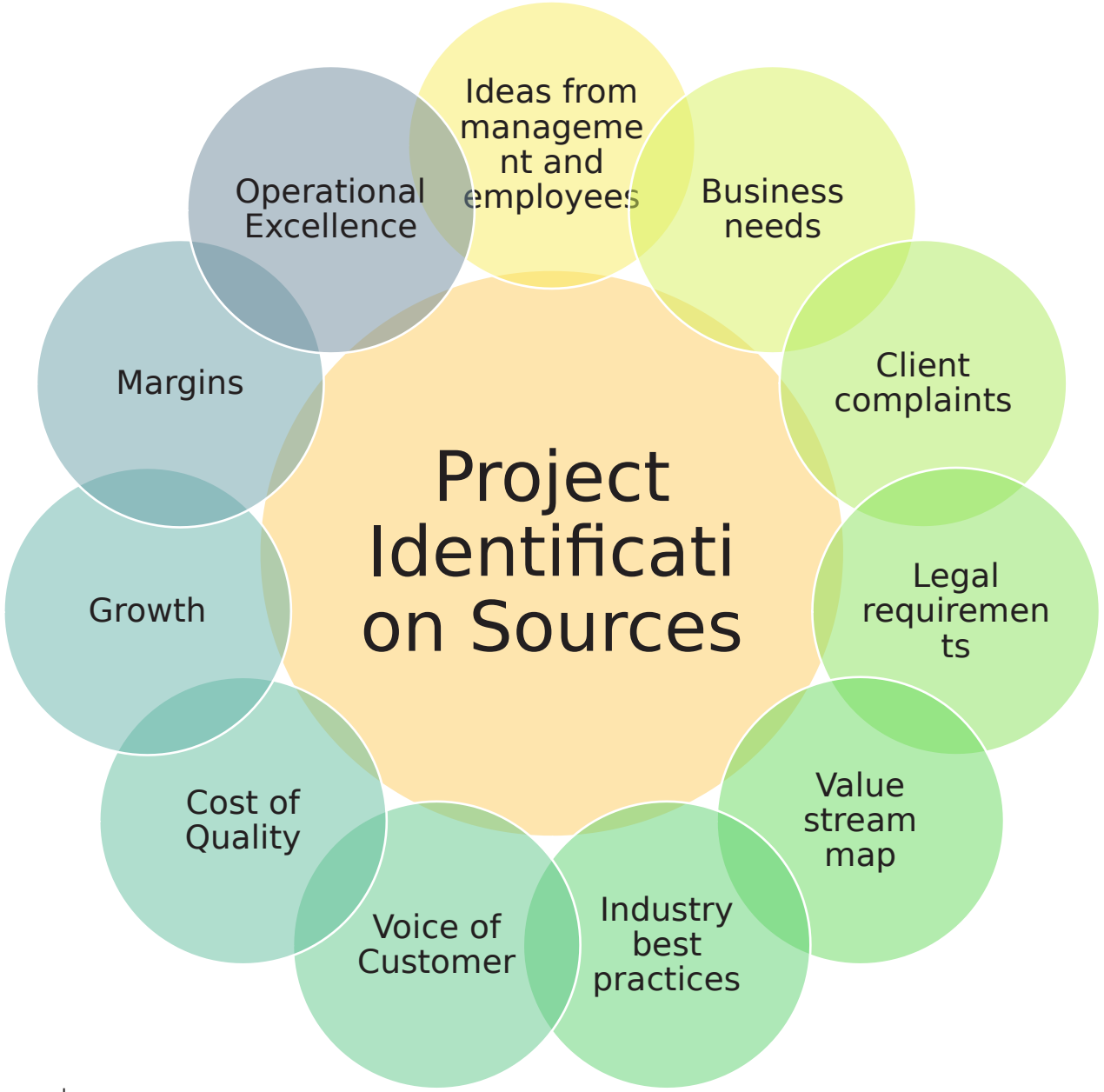
# Opportunities Identification - Themes





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# Opportunities Identification – Example

| |
|---|
| What do customer want from your products and services? |
| Is there a short fall? |
| Where flow is interrupted |
| Where defects occur and hurting the business? |
| What else hurting the business |
| Areas of daily firefighting in business |
| Key performance indicators (KPIs) |
| Productivity, quality, and customer satisfaction, areas that are underperforming or gaps in performance |
| Benchmarking against industry standards |
| Internal weaknesses and external threats |
| Areas of trouble, frustration |
| Are the current processes and procedures enough |


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# Introduction

- ✓ Name
- ✓ Team Name
- ✓ Role
- ✓ Work Experience
- ✓ Why do you want to attend this session
- ✓ What do want to take away
- ✓ One Exciting thing about you


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# INDEX


Module 1 – Evolution & Introduction to Lean Six Sigma

Module 2 – Define Phase

Module 3 – Measure Phase

Module 3 – Analyze Phase

Module 4 – Improve Phase

Module 6 – Control Phase & Project Closure



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Module 1

# Evolution & Introduction to Lean Six Sigma


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# What is Sigma?

Sigma is a letter in the Greek Alphabet

Sigma is a Symbol which shows the degree of variation in a process (standard deviation)

As an upper case letter (∑), it is used as a symbol for sums and series in which each term is computed from the previous one by adding (or subtracting) a constant. Sigma is used to add all parts, in sequence, to give a total made up of every number in the sequence.

**How close are you to meet your target?**

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# Six Sigma - A Breakthrough Strategy

A Business Management Strategy developed by Bill Smith (Father of Six Sigma)Motorola,USA,1981

It is a methodology for continuous improvement

It is a set of statistical and other quality tools arranged in a unique way

A Problem Solving technique, Statistically Approached, A  Quality Philosophy, Out of Box thinking

Applied to existing processes and products

Improves  the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability_in manufacturing and business processes

Accuracy: 99.9997%  free of defects(3.4 defects per 1 million)

***We gain a competitive edge in Quality, Cost, Customer Satisfaction***


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# Fundamental Definition

The fundamental definition of Six Sigma capability refers to a process where "the center of the process is away from the nearest specification limit by six standard deviations of the process".

It is a set of statistical and other quality tools arranged in a unique way.

It is a way of knowing where you are and where you could be!


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# Origin of Six Sigma

**MOTOROLA**

**The company that invented Six Sigma**

The term “Six Sigma” was coined by Bill Smith, an engineer from Motorola

Late 1970s- Motorola started experimenting with problem solving statistical analysis

1987- Motorola officially launched its Six Sigma program


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# The Growth of Six Sigma

**GE**

**The company that perfected Six Sigma**

Jack Welch launched Six Sigma at GE in Jan, 1996.

1998/99- Green Belt exam certification became the criterion for management promotions

2002/03- Green Belt certification became the criterion for promotion to management roles


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# Business Cost Model

## Old Model

**Cost + Profit = Sales**

**Price**

- Price set by adding profit margin on top of cost
- Few choices for customer
- Value is customer perception

## New Model

**Price - Cost = Profit**

- Ongoing cost reduction activities
- More choices for customer
- Increase profits
- Possibly lower sales price

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# Cost of Poor Quality

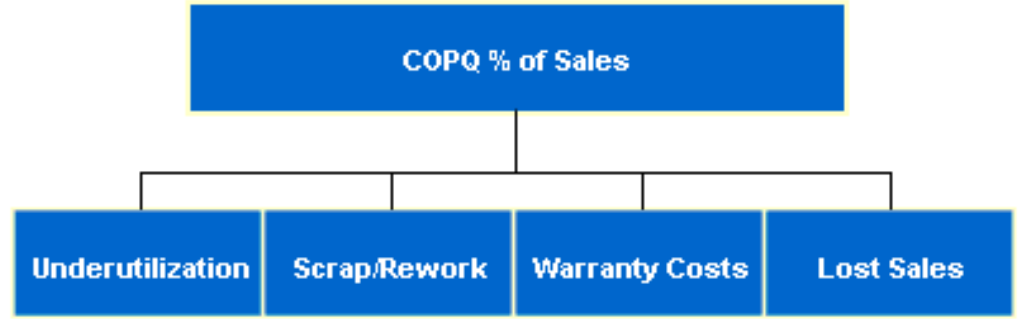
COPQ % of Sales
Underutilization
Scrap/Rework
Warranty Costs
Lost Sales
Planned overcapacity to anticipate low yield (Incremental annual depreciation expense)
Scrap costs
Rework costs
Non - material rework costs (sorting, handling, downtime and expedited shipping)
Warranty Costs (Includes Customer Credits, RMA costs, Rework Costs and Restocking costs)
SLA Penalties
Lost Revenue
Customer Churn Costs
Excess Inventory carrying costs (due to fewer sales)

Figure 1: A Framework used by a Fortune 500 company for Calculating COPQ

**Cost of poor quality** (COPQ) or **poor quality costs** (PQC), are **costs** that would disappear if systems, processes, and products were perfect. COPQ was popularized by IBM **quality** expert H. James Harrington in his 1987 book **Poor Quality Costs**.


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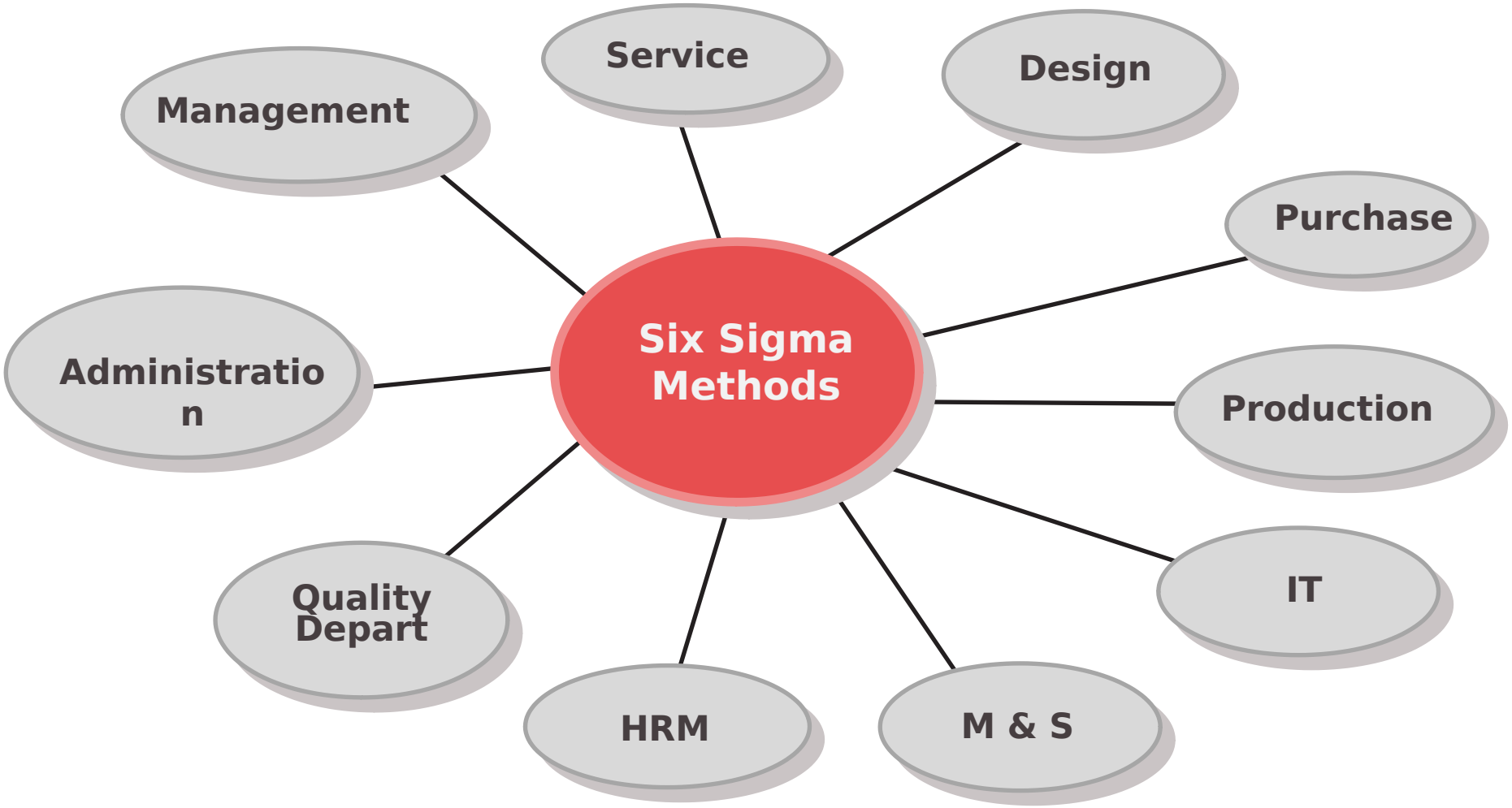
# Where can Six Sigma be applied?





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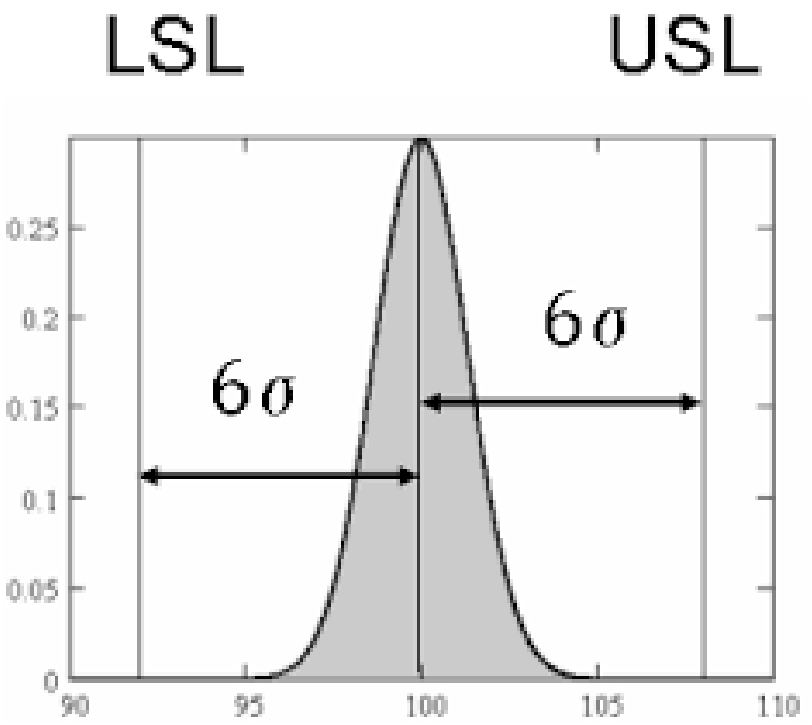
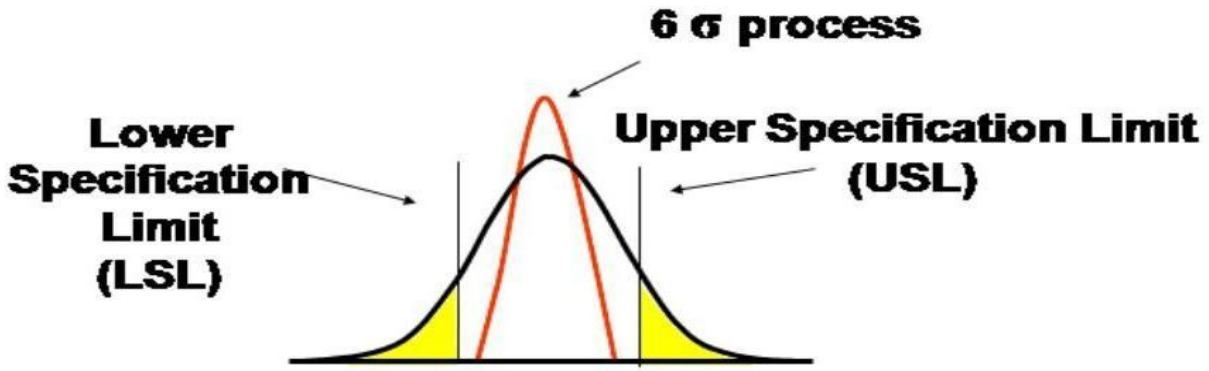
# Variation




True Six Sigma process

## Understanding Variation

Higher σ = less variation
= fewer defects
= better performance





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# DMAIC- Phases

| | | |
|---|---|---|
| *Define* | 1. | What are customer expectations of the process? |
| *Measure* | 2. | What is the frequency of defects? |
| *Analyze* | 3. | Why, when, and where do defects occur? |
| *Improve* | 4. | How can we fix the process? |
| *Control* | 5. | How can we make the process stay fixed? |


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# The Approach

Practical Problem

Statistical Problem

Statistical Solution

Practical Solution

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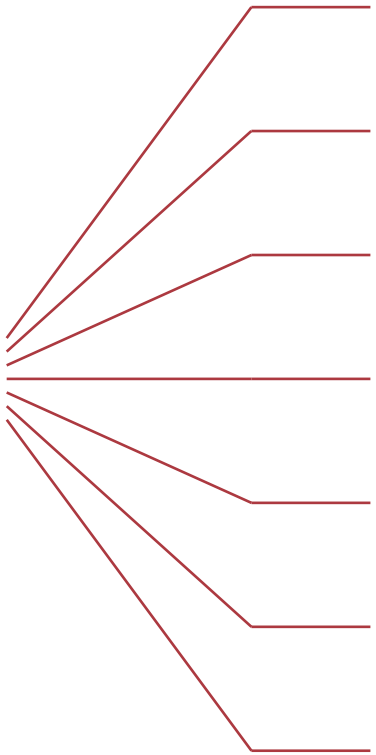
# Six Sigma: Challenges and Misconception

Here is a close look at some misconceptions about Six Sigma:



- It is just for manufacturing.
- Proper implementation needs a statistical genius.
- Six Sigma needs heavy investment on resources and systems.
- It can be used only to handle big projects.
- It can be done part time.
- It needs only a clear understanding of statistical packages.
- It can be used to solve day-to-day problems in processes.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## Module 2

# Introduction to Define


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**Key Objective:** Define the Project

**Key Deliverables:** Completed Project Charter & High Level Process Map

## Roadmap of the Define Phase:

- Alignment: Make sure that project leader & project sponsor are in alignment with the business strategic imperatives, scope, improvement goals, timeline and estimated benefits. All these details should be put in the project charter
- Team launch: A project team should be chosen & launched formally.
- SIPOC: High Level Process Map should be prepared with all team members
- Toll Gate Review: Toll gate review to be conducted with Sponsor, Black Belt & Project leader


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# Define Phase – Y is a function of X's (multiple inputs impacting output)

The mathematical term *Y = f(x)*, which translates as simply "*Y* is a function of *x*," illustrates the idea that the important process outcomes (*Y*s) are a result of the drivers (*x*'s) within processes. The goal of DMAIC is to identify which few process and input variables mainly influence the process output measures. Each DMAIC phase can therefore be described by how it contributes to this goal:

**Define:** Understand the project *Y* and how to measure it.

**Measure:** Prioritize potential *x*'s and measure *x*'s and *Y*.

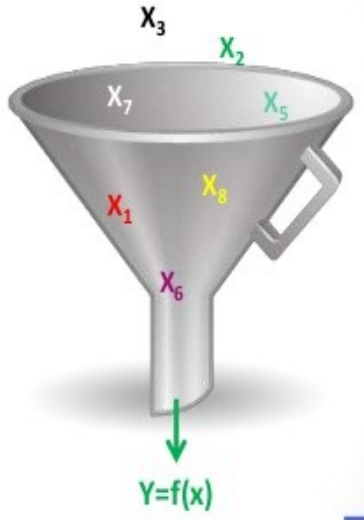
**Analyze:** Test *x*–*Y* relationships and verify/quantify important *x*'s.

**Improve:** Implement solutions to improve *Y* and address important *x*'s.

**Control:** Monitor important *x*'s and the Y over time.

## Y=f(x) Approach

- Six Sigma Approach
  - Y=f(x) is the relational transfer function that is used by all Six Sigma practitioners.
- Y refers to the measure or output of a process.
  - The "Y" is the measure of process performance that you're trying to improve.
- f(x) means "function of x".
  - x's are factors or inputs that affect the "Y"
- In simple terms: "My process performance is dependent on certain x's".





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# Develop Project Charter

## Business Case

- Why is the project worth doing?
- Consequence of not doing the project.

## Problem Statement

- Description of pain
- What does not meet the customer’s needs

## Goal Statement

- Improvement that the team is seeking to accomplish

## Scope

- What will the team work with on and what is out-of-bounds

## Milestone

- Project plan with dates

## Project team

- Project team members


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## TEAM/PROJECT CHARTER

| | |
|---|---|
| **Project Name:** | |
| **Date (Last Revision):** | |
| **Prepared By:** | |
| **Approved By:** | |

| **Business Case:** | **Opportunity Statement (High Level Problem Statement):** |
|---|---|
| | Defect Definition: |
| **Goal Statement:** | **Project Scope:** |
| | Process Start Point: |
| | Process End Point: |
| Expected Savings/Benefits: | In Scope: |
| | Out of Scope: |

**Project Plan:**

| Task/Phase | Start Date | End Date | Actual End |
|---|---|---|---|
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**Team:**

| Name: | Role: | Commitment (%): |
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# Project Charter

Project charter is dynamic.

It continues to evolve throughout the project.

It sets a direction and objectives.

It explains why the project is an important investment of time & resources.

After appointment of the champion, members are listed and their roles are defined.

A Black Belt is chosen who clarifies the project rationale with the champion.

It is crucial to describe the project title.

Project title should allow others to understand the purpose of the project at a glance.


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# Identifying Customers

**Who are the customers?**

This question is the vital first step in any Six Sigma Project.

Team should begin the project by identifying all customers.

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# Identifying VOC

**Description:**

The Voice of the Customer (VOC) are the customer specifications. This can include variable data such as the:

Lower Specification Limit (LSL)Upper Specification Limit (USL)Target Value (or Nominal Value)

The customer may specify only one specification limit and the target value is not necessarily the midpoint of the specifications. Don't assume this value, ask the customer for the target value if one exists.

The VOC may also involve attribute specifications such as a "number of ...", color type, or PPM rating.

**IMPORTANT:**
The VOC provides specification limits (LSL. USL). This is NOT the same as the VOP which provides the control limits (LCL, UCL). The VOP describes the width of the data and can change with every new data point, in other words the LCL and UCL are formulae whose values are changing to describe the process behavior. The specification limits (VOC) are constants, unless the customer informs of a change.

The VOC will be referenced and verified throughout the project and ultimately at the closing of the project and hand-off to the Process Owner.


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# Identifying VOC

**Sources of the Voice of the Customer are:**

- Surveys
- Past complaints
- Service issues
- Quality issues
- Delivery issues
- Customer scorecards
- Marketing research
- Data studies of patterns and trends
- Audits
- Past decision behavior and tendencies
- Technology research
- Focus Groups
- Interviews

Customer needs, wishes, desires, mandates, attitudes are dynamic. Keeping up with trends and predicting behaviors separates the best and better products, processes, and services. Although it is very important for any Six Sigma project, it is especially important when developing an unprecedented product or process in a DFSS project. The more that can be obtained the better. Be cautious on the approach and strategy, delicately balancing the team's desire to obtain all possible information without annoying the customer, leaking a potential competitive edge, or tying up to many resources.


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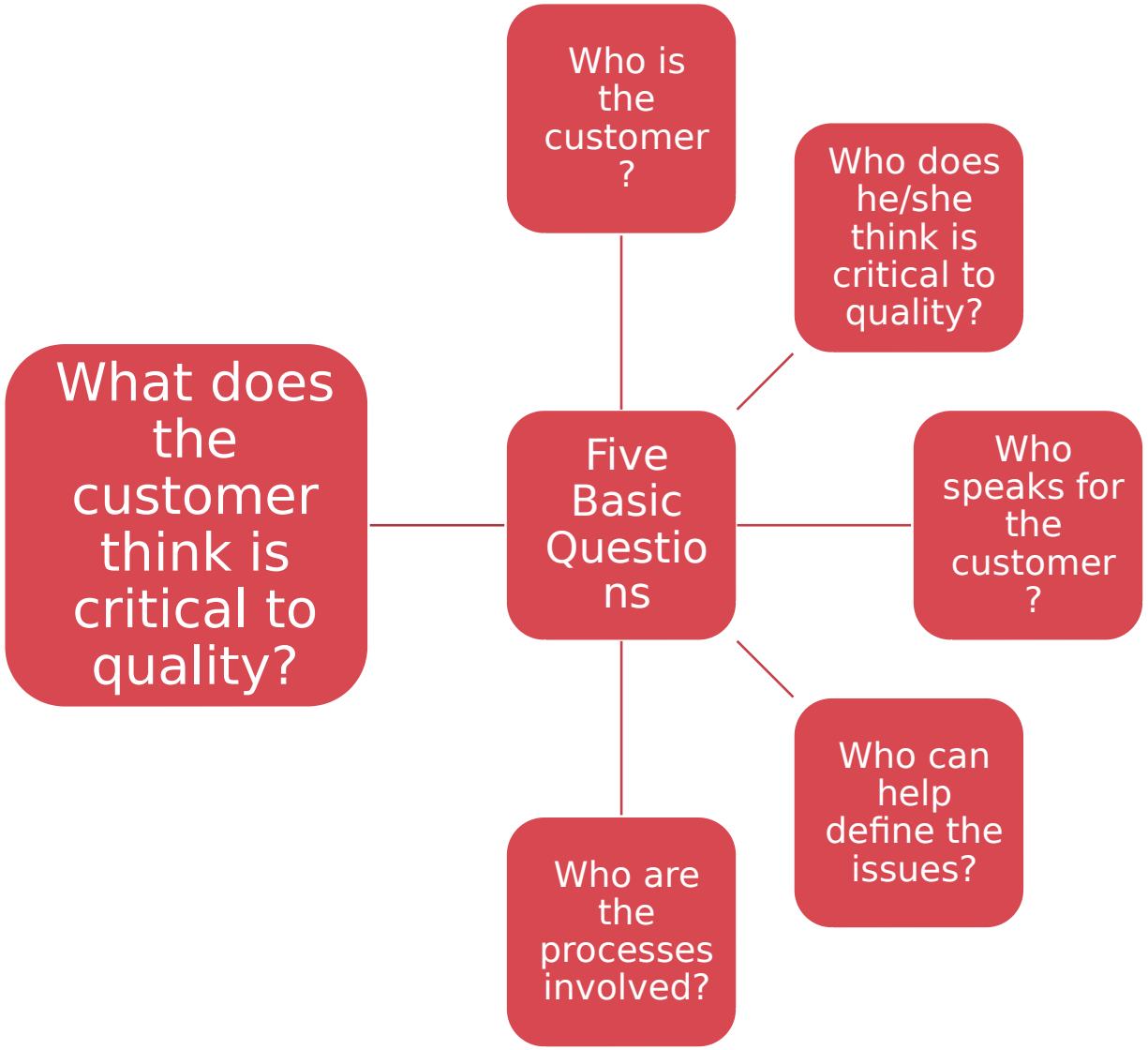
# Identify Project CTQ


What does the customer think is critical to quality?
Five Basic Questions
Who is the customer?
Who does he/she think is critical to quality?
Who speaks for the customer?
Who can help define the issues?
Who are the processes involved?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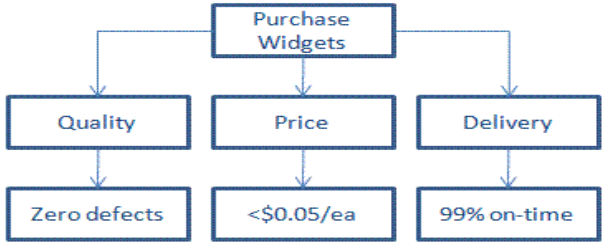
# Establishing VOC to CTQ

**Description:**

The CTQ linkage is a graphical depiction to show a clear link to the needs that are critical to quality from the perception of the customer. The chart begins with the most elementary needs and more levels are added as needed and exact metrics are not necessary at this time.

The CTQ breaks down customer requirements into quantified requirements. This may include targets and upper and lower specification limits.

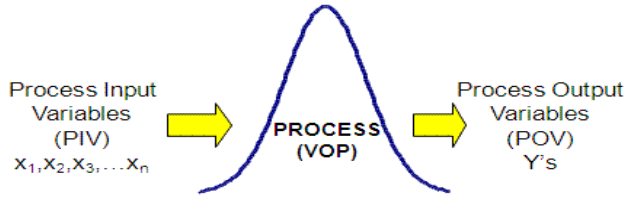
The customer is also the company you work for. Including their requirements (ROI, cash, time schedule) is also important. Below is a very basic form of a CTQ Flow-down.




$$Y = f(x_1, x_2, x_3, \ldots x_n)$$

Effect = function of inputs (causes)

The effect should be a positive gap closure to satisfying the needs of the customer




Process Output Variables (POV) Y's → Critical To Quality (CTQ) Quality/Delivery/Cost from Voice of Customer (VOC)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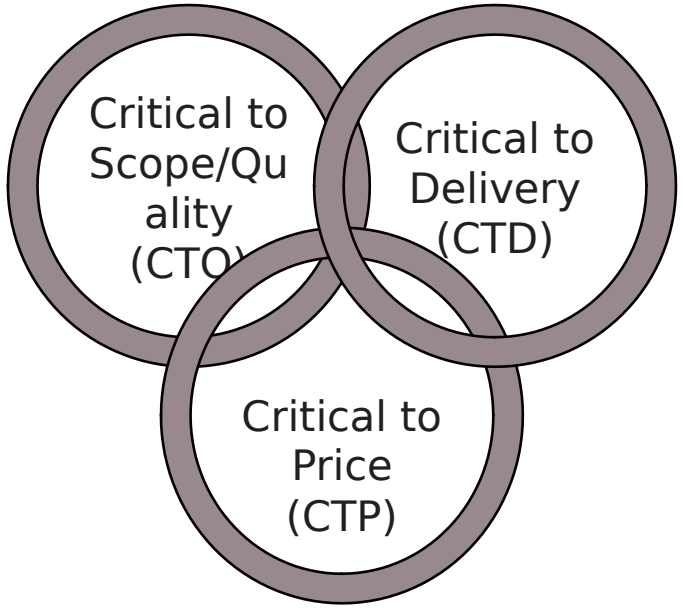
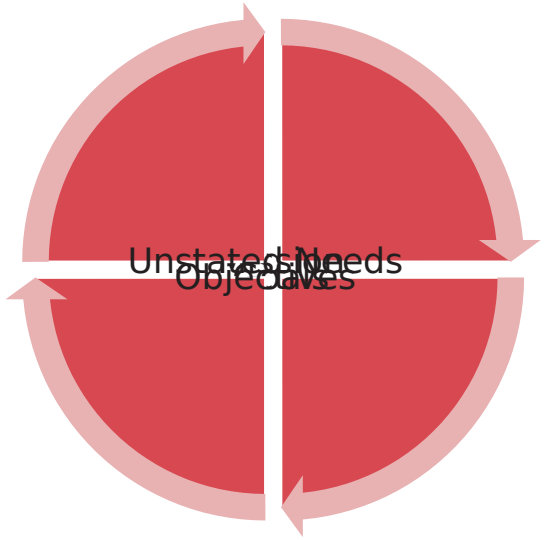
# Project Metrics

Selection of project metrics is a crucial element of the project charter.

It reflects the Voice of Customers (VOC) & Voice of Business (VOB).

Metrics are according to any of  the three dimensions




Metrics should be simple, straightforward, meaningful, easily understandable.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# Scope of the Project

Project scope/definition is the boundary within which the Six Sigma team works.

It ensures that the team focuses on the

**Biggest Problem, Best Opportunity.**

- Determine scope properly and achieve 70% of benefits rather than chase after 100% of benefits and then fail.
- Improper scope can undermine a project and even make it fail.
- Larger scope should be divided into smaller and realistic scope.

**Suggestions for understanding the scope of Six Sigma Projects:**

Check other projects affecting the project being scoped.

Clarify project expectations.

Focus on finances.

Keep time in mind.

Keep the project from crossing boundaries.


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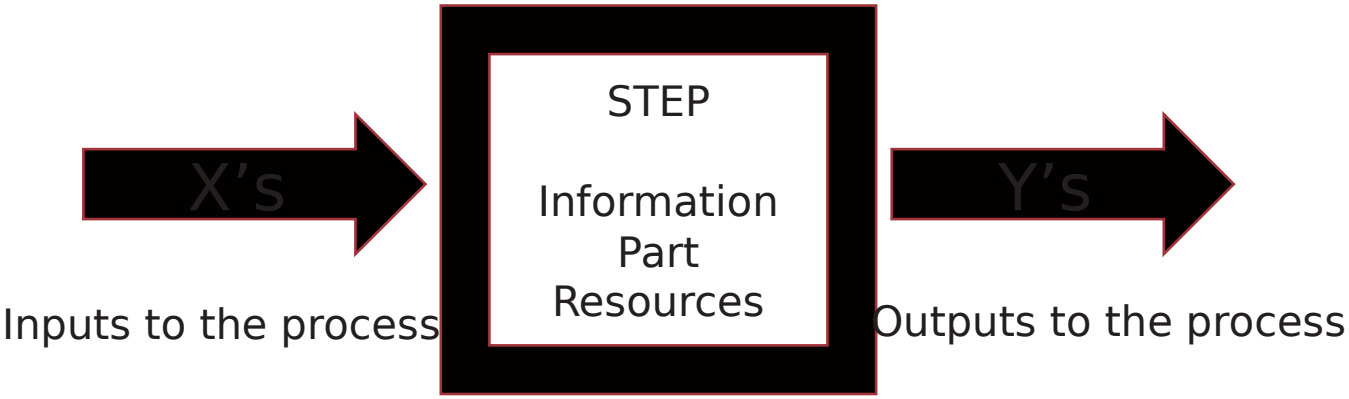
# Process Mapping : Step

$Y = f(X_1 \ldots\ldots X_N)$




Inputs to the process

Outputs to the process

Metrics to track : (Defect Rate = DPU), Cycle Time

**Key Questions that must be answered:**

Why do you do this step?

How do you know it is good?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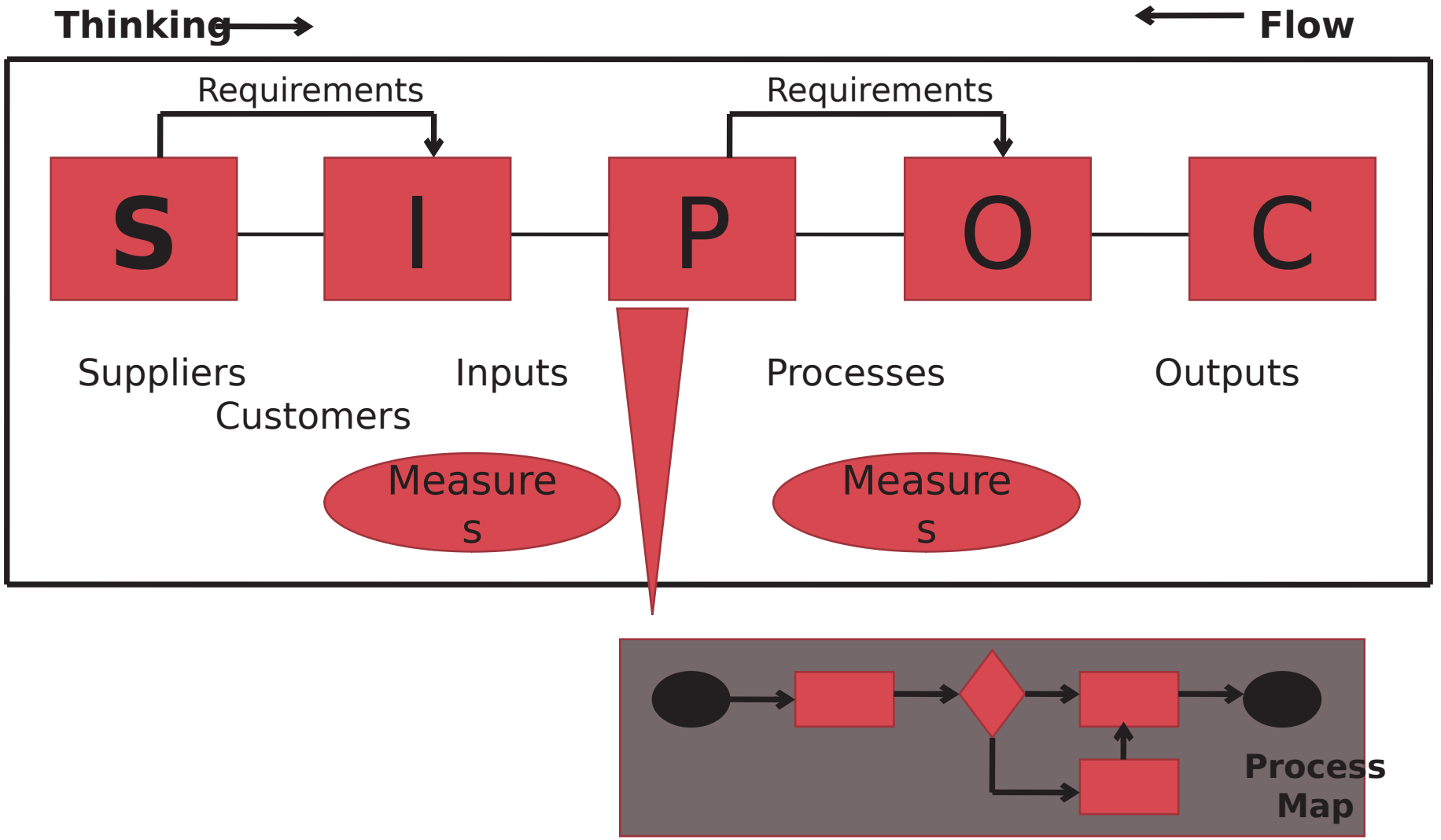
# High Level Process Mapping





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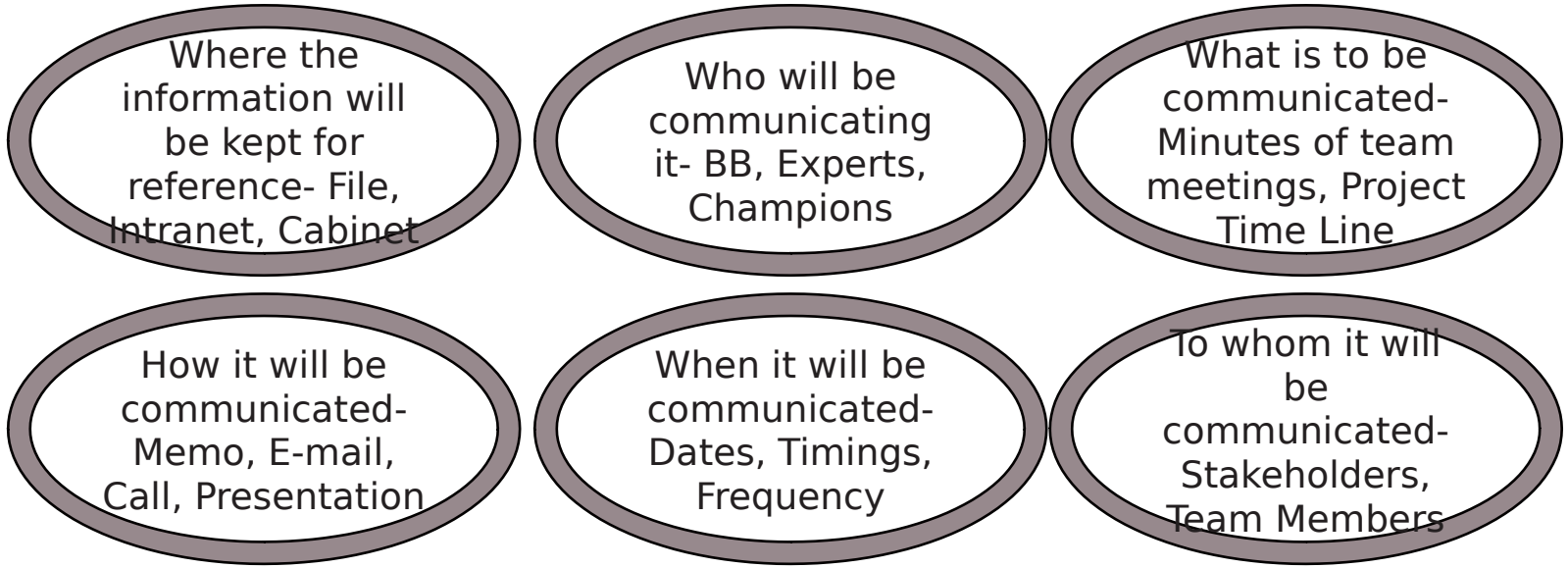
The BB, MBB and the Champion develop the preliminary project plan into a detailed project plan.

Project plan structures the project into-

- Steps
- Schedules milestones
- Deliverables
- Goals for the five phases


Where the information will be kept for reference- File, Intranet, Cabinet
Who will be communicating it- BB, Experts, Champions
What is to be communicated- Minutes of team meetings, Project Time Line
How it will be communicated- Memo, E-mail, Call, Presentation
When it will be communicated- Dates, Timings, Frequency
To whom it will be communicated- Stakeholders, Team Members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# Obtain Approval for the Project

The BB & the champion should present—

| Project Charter | Business Case | Preliminary Project Plan | Request for Financial Support | Request for reviewing and approval |
|---|---|---|---|---|

If the project is approved and resources are allocated, the team continues through Define Phase.

If not, the executive team asks the BB/champion to rework the charter.

The focus of the meeting should be to help the members of executive team learn from the findings reported by project team.

The project team will prepare a final report on the lessons learnt when it completes a project.


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# DEFINE PHASE - Check List of Toll Gate Review Questions

**MAIN OBJECTIVE:** Define the Project

**REQUIRED DELIVERABLES:** Project Charter, SIPOC

| **TOLL GATE QUESTIONS:** | |
|---|---|
| | Does the Problem Statement detail the problem, *when* and *where* the pain occurs? |
| | Does a Goal Statement define the metric(s) to improve? Does the improvement target seem achievable? |
| | Are the Project Scope and Time Line reasonable? Have constraints and key assumptions been identified? |
| | Does the expected Business Impact (once the improvement target has been reached or exceeded) still justify the project? |
| | Have the customers been identified? What are their requirements? Are they measurable? How were the customer requirements determined? |
| | Who is on the team? Do they all understand the elements of the Project Charter? |


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## Module 3

# Introduction to Measure


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## Key Objective: Process Baseline

## Key Deliverables: Data Collection Plan, Process Baseline

## Roadmap of the Measure Phase:

- Data Collection Plan: Ensure accurate operational definitions of process metrics & sampling plan
- Measurement System Analysis: Check if the measurement system is reliable & stable
- Process Baseline: Calculate process baseline based on historical data
- Process Capability: Calculate process capability (Cp/Cpk, DPMO)
- Toll Gate Review: Toll gate review to be conducted with Sponsor, Black Belt & Project leader


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# Data Classification

## Numeric / Quantitative

- Continuous - Height, Weight, Distance
- Discrete –
  - Count
  - Proportion

## Non Numeric / Qualitative

- Binary – Yes/No
- Ordinal – Low/Medium/High
- Nominal – Red, Green, Black, White


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# Plan For Data Collection

**1 Establish Data Collection Goals**

- Clarify purpose of data collection
- Identify what data to collect

**2 Develop Operational Definitions And Procedures**

- Write and pilot operational definitions
- Develop and pilot data collection forms and procedures
- Establish a sampling plan

**3 Ensure Data Consistency And Stability**

- Through measurement systems

**4 Collect Data And Monitor Consistency**

- Train data collectors
- Collect data
- Check for data accuracy and consistency


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# Cause of Variation

## Common Cause Variation

Common Cause Variation is the **variation present in every process.** Also known as **white noise**.

It is **not controllable** variation within the existing technology.

Represents the best the process can be with the present technology(Inherent process capability).

## Assignable Cause Variation

Assignable Cause Variation represents the **outside influences on a process** that cause average to shift and drift. Also known **as special cause**.

It is **potentially controllable** variation with the existing process technology.

It represents how the process is actually performing over time(Sustained process capability).


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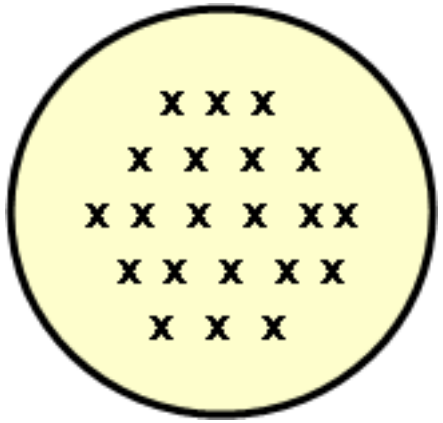
**Sampling is the process of** Collecting only a portion of the data that is available or could be available, and drawing conclusions about the total population (Statistical Inference)

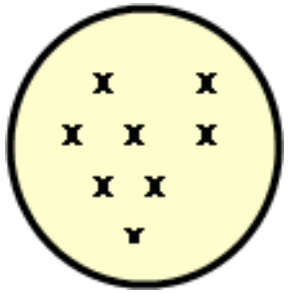
**Population**



**N = 50,000**

Population is 50,000 movie goers of New Delhi

**Sample**



**n = 100**

From the sample, we infer that the average time in the ticket queue(y) is 22mins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# Sampling Methods/Strategies

| | | |
|---|---|---|
| **Best Methods for Six Sigma Data:** | **Random** | *Best approach for Population situations.* Use a random number table or random function in Excel or other software, or draw numbers from a hat. |
| | **Systematic** | ***Most practical and unbiased in a Process situation***. "Systematic" means that we select every nth unit, or take samples at specific times of the day. The risk of bias comes when the timing of the sample matches a pattern in the process. |
| | **Stratified** | Divide subjects into subgroups called strata based on characteristics that they share (e.g., race, gender, educational attainment) |


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# Sampling Methods/Strategies

The big pitfall in sampling is “bias” – i.e., select a sample that does NOT really represent the whole. The sampling plan needs to guard against bias. Different methods of sampling have different advantages and disadvantages in managing bias.

| | |
|---|---|
| **Judgment** | As it sounds – selecting a sample based on someone’s knowledge of the process, assuming that it will be “representative.” Judgment guarantees a bias, and should be avoided. |
| **Convenience** | Also just like it sounds – sampling those items or at those times when it’s easier to gather the data. (For example, taking data from people you know, or when you go for coffee.) This is another common (but ill-advised) approach. |


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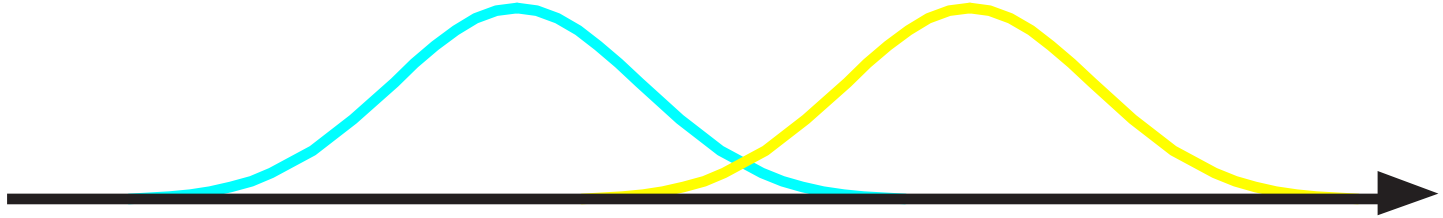
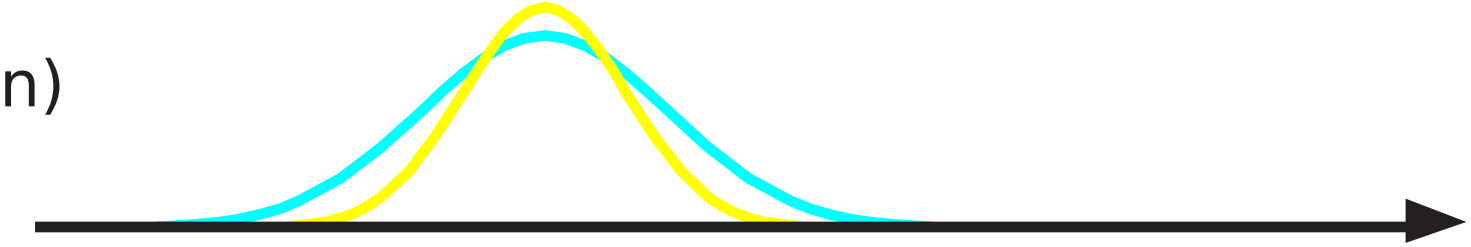
# Numerical Data Properties

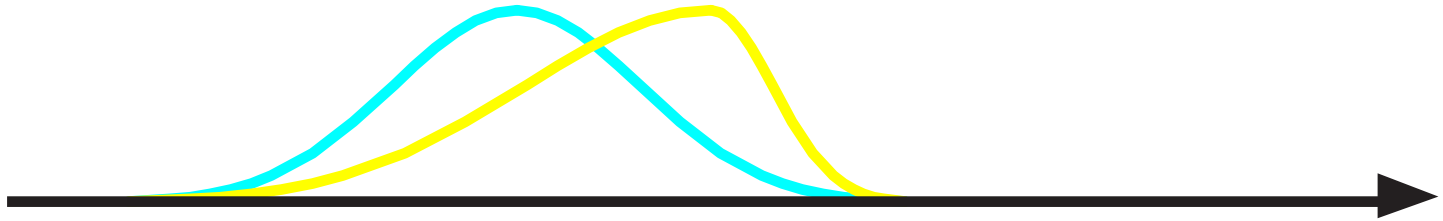
Central Tendency (Location)



Variation (Dispersion)



Shape

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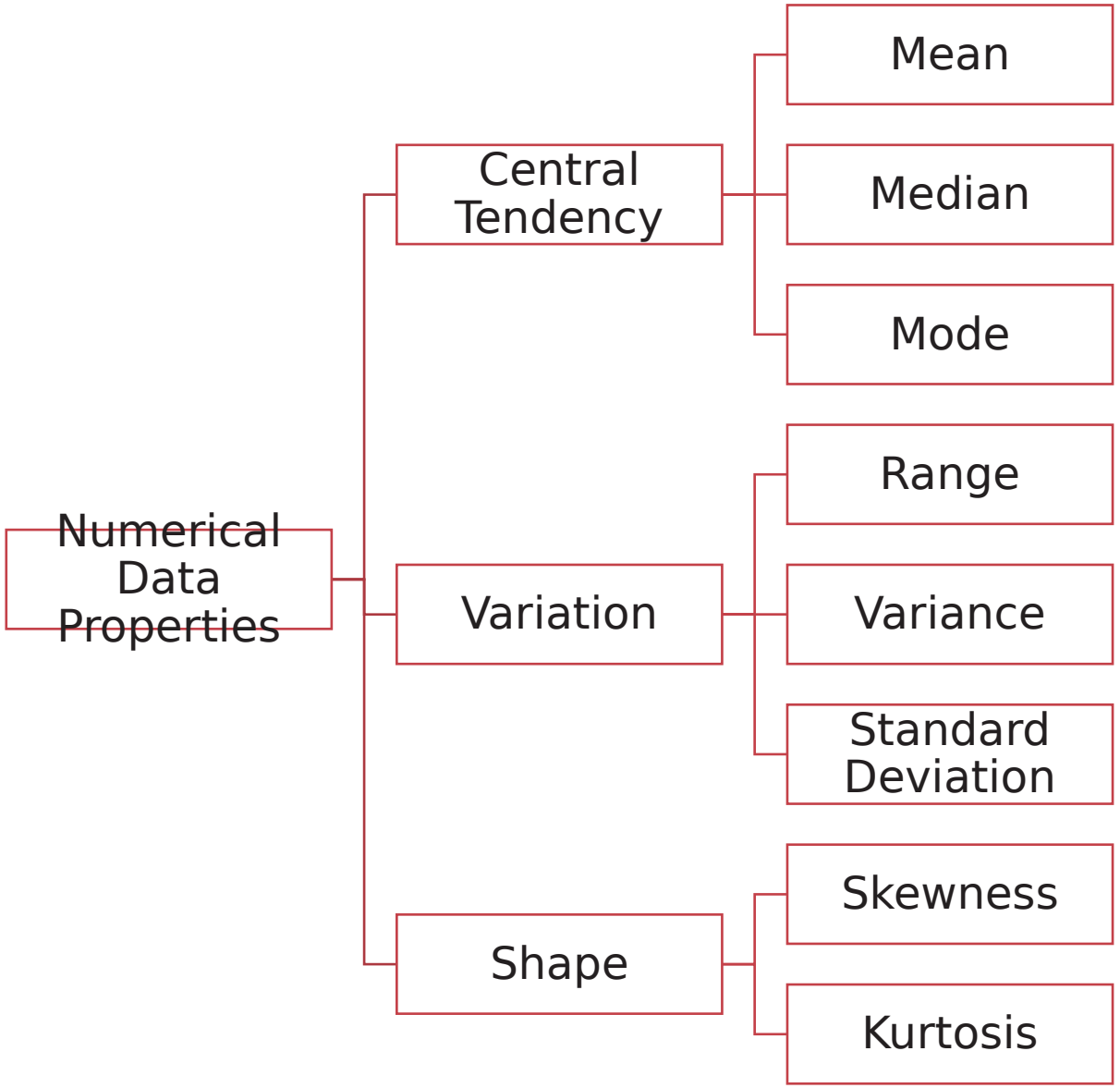
# Numerical Data Properties & Measure





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# Mean

- Measure of Central Tendency
- Most Common Measure
- Acts as ‘Balance Point’
- Affected by Extreme Values (‘Outliers’)
- Formula (Sample Mean)

$$\frac{\text{Sum of all data } (X_i)}{\text{Number of data (n)}}$$

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{X_1 + X_2 + \cdots + X_n}{n}$$


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# Median

- Measure of Central Tendency
- Middle Value In Ordered Sequence
  - If Odd n, Middle Value of Sequence
  - If Even n, Average of 2 Middle Values
- Position of Median in Sequence
- Not Affected by Extreme Values

$$\text{PositioningPoint} = \frac{n+1}{2}$$


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# Mode

- Measure of Central Tendency
- Value That Occurs Most Often
- Not Affected by Extreme Values
- May Be No Mode or Several Modes
- May Be Used for Numerical & Categorical Data


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# Summary of Central Tendency Measures

| Measure | Equation | Description |
|---|---|---|
| Mean | $\Sigma X_i / n$ | Balance Point |
| Median | $\frac{(n+1)}{2}$ Position | Middle Value When Ordered |
| Mode | none | Most Frequent |


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# Range

- Measure of Dispersion
- Difference Between Largest & Smallest Observations
- Ignores How Data Are Distributed

$$\text{Range} = X_{largest} - X_{smallest}$$

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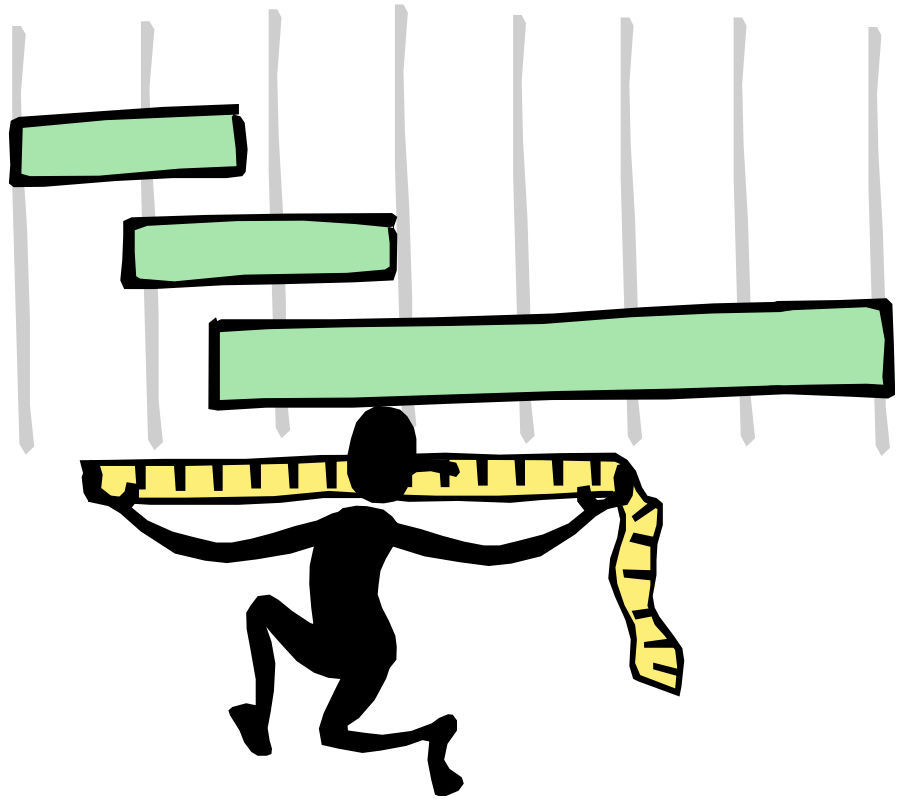
## Range :

- Is a measure of spread and it is calculated by subtracting the smallest number from the largest.
- Ex) 4, 5, 7, 11, 14, 14, 15
- Range = max – min = 15 – 4 = 11

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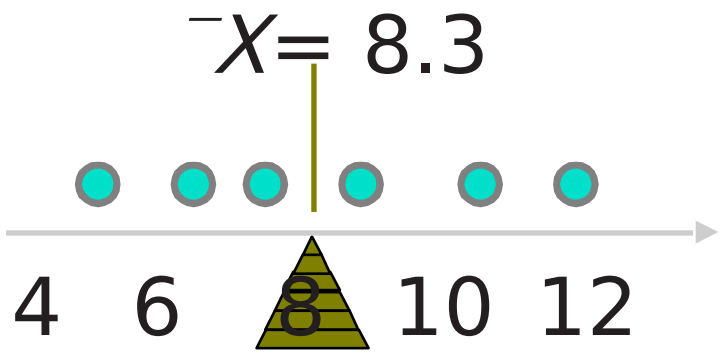
# Standard Deviation

- Measures of Dispersion
- Most Common Measures
- Consider How Data Are Distributed
- Show Variation About Mean ($X$ or $\mu$)





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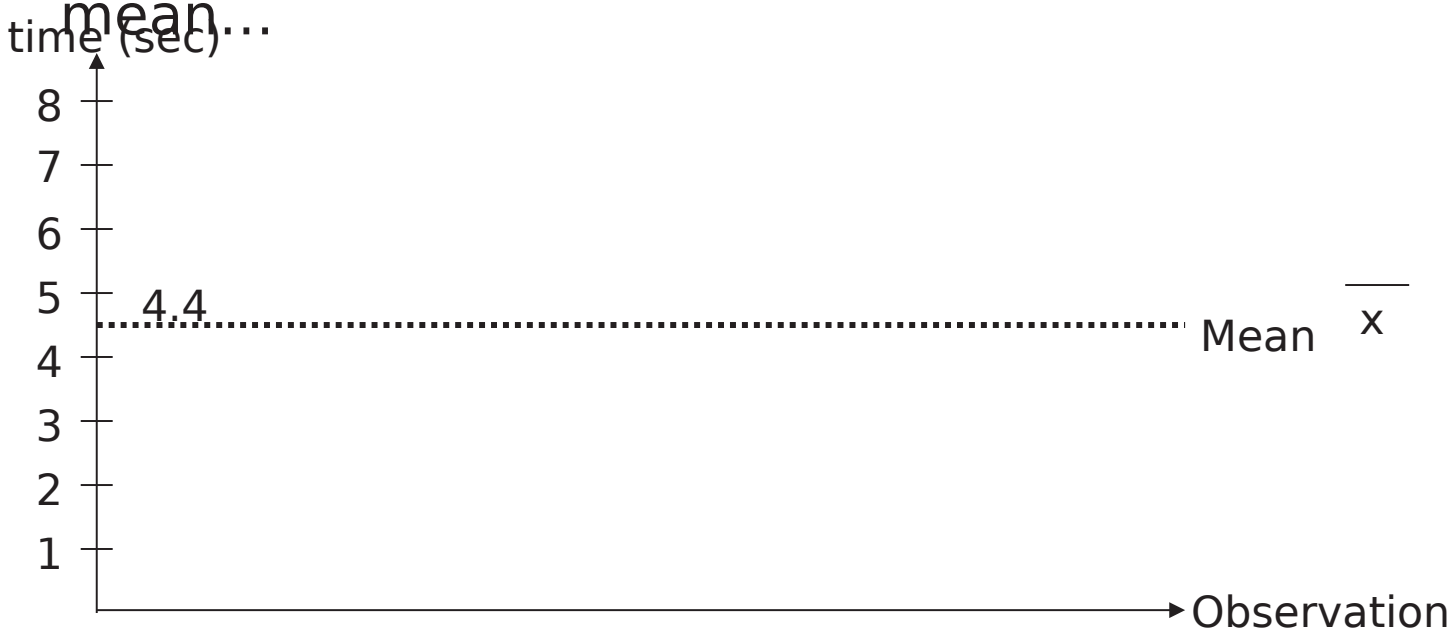
## Standard deviation :

- The average of the distances between the observations and the mean…




- Standard deviation has the same dimension as the measurements (e.g., mm, seconds, kg)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**Standard deviation :**

Commonly used measurements for spread represented by σ and calculated by the formula :

$$\sigma = \sqrt{\frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \ldots + (X_n - \overline{X})^2}{n-1}}$$

- Where $\overline{X}$ = mean
- $X_1, X_2 \ldots$ = the values in our group of data
- n = the number of values in our group of data
- Other denotations for the standard deviation is s and Sigma


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**Standard deviation :**

- Ex. 1, 2, 3, 4, 5 X $\overline{X} = 3$

$$S = \sqrt{\frac{(1-3)^2 + (2-3)^2 + (3-3)^2 + (4-3)^2 + (5-3)^2}{5-1}}$$

$$\sqrt{\frac{(-2)^2 + (-1)^2 + (0)^2 + (1)^2 + (2)^2}{4}} \quad \sqrt{\frac{4 + 1 + 0 + 1 + 4}{4}}$$

$$= \sqrt{10 / 4} \quad = \sqrt{2.5} \quad = 1.58$$


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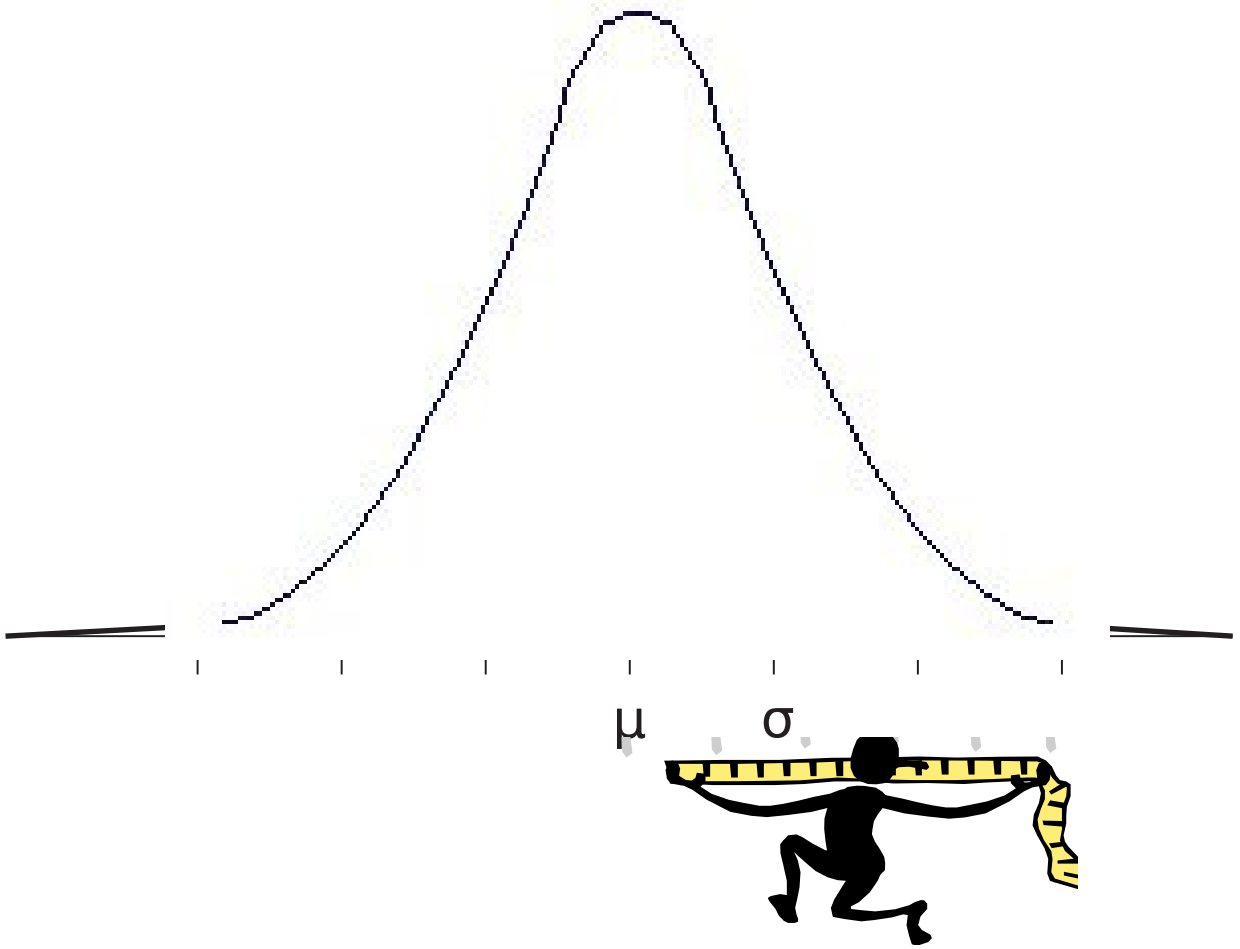
# Standard Deviation

- We <u>always</u> strive to ha

possible!





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**A Swedish long distance runner has competed in 15 marathons in the last three years (see matrix below)**

a) Calculate the average time it took to run the five marathons in 2002, 2003 and 2004

b) Calculate the median for how long time it look to run marathon for each year

c) Calculate the range for each year

d) Calculate the standard deviation for each year

# Time : 20 minutes


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| (Minutes) | 2002 | 2003 | 2004 |
|---|---|---|---|
| New York | 140 | 138 | 135 |
| Stockholm | 145 | 142 | 136 |
| London | 155 | 145 | 134 |
| Boston | 160 | 145 | 135 |
| Sydney | 150 | 240 | 140 |

**Extra :**

1.Calculate the average time it has taken to run all 15 marathons during 2002-2004

2.Calculate the average median for how long time it has taken to run all 15 marathons during 2002-2004

3.Calculate the range for all 15 marathons that the runner ran during 2002-2004

4.Calculate the standard deviation for the total number of marathons during 2002-2004


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# Standard Notation

| Measure | Sample | Population |
|---|---|---|
| Mean | $\bar{X}$ | $\mu$ |
| Stand. Dev. | $S$ | $\sigma$ |
| Variance | $S^2$ | $\sigma^2$ |
| Size | $n$ | $N$ |


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# Six Sigma Metrics

$$DPU = \frac{\text{TOTAL \# DEFECTS}}{\text{TOTAL \# UNITS}} = \frac{D}{U} = \frac{14}{10} = 1.4$$

$$DPO = \frac{DPU}{O} = \frac{1.4}{4} = 0.35$$

$$DPO = \frac{D}{U \times O} = \frac{14}{10 \times 4} = 0.35$$

$$DPO = \frac{D}{TOP} = \frac{14}{40} = 0.35$$

$$DPMO = DPO \times 10^6$$

$$DPMO = 0.35 \times 10^6 = 350{,}000$$

PPM = defectives percentage of a population x $10^6$

PPM = 0.70 x 1,000,000 = 70,000

**Example Used Above:**

**D** = # defects (14)

opportunities (40)

**O** = # defect opportunities (4)

**U** = # units (10)

**TOP** = total # of failure

**DPU** = defects per unit (1.4)

**Note: Parts per Million (PPM)**

PPM counts the quantity of defective parts per million parts produced. As noted above, it does not account for the fact that multiple defects may affect a single part. One defective part, even with multiple defects, counts as a single defective among other defectives in the population. As with DPMO, it uses 1,000,000 as a constant, regardless of the actual number of parts produced. The formula is:


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# Six Sigma Metrics – Continued….

## First Pass Yield (FPY), or Throughput Yield (TPY), and First Time Yield (FTY), Rolled Throughput Yield (RTY)

$$\text{FPY / TPY} = \frac{\text{\# UNITS DEFECT-FREE}}{\text{\# UNITS ENTERED PROCESS}}$$

$$\text{FPY/TPY} = \frac{6}{10} = 0.60$$

RTY= (Y1) (Y2) (Y3) (Y4) … (Yn) where Y is the yield (proportion good) for each step

For example, a four-step process has a yield of 0.98 in step 1, 0.95 in step 2, 0.90 in step 3, and 0.80 in step 4.

RTY = (0.98)(0.95)(0.90)(0.80) = 0.67032


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## Module 4

# Introduction to Analyze


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# Analyze Phase

| | |
|---|---|
| **Key Objective:** | Validated Root Causes |
| **Key Deliverables:** Effect matrix | List of potential root causes & validated Root Causes, Cause & |
| **Roadmap of the Analyze Phase:** | Identify Potential Root Causes (Xs): |
| | Filter Potential Root Causes: Filter potential root causes using **Impact/Control matrix.** |
| | Validate Root Causes: Validate root causes using statistical methods |
| | Estimate impact of each ‘X’ on ‘Y’ |
| | Prioritize Root Causes: Prioritize root causes using **Urgent/Important Matrix** |
| | Toll Gate Review: Toll gate review to be conducted with Sponsor, Black Belt & Project leader |


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# Optimizing the Project Plan

Once you have created the project plan, verify that it meets the project stakeholders' date, resource, and cost requirements. If an inconsistency exists between the information in the project plan and the project requirements, you will be able to identify the source of the problem and define a solution:

– Analyse schedule dates

Evaluate the schedule to ensure that milestone dates and project dates are achieved.

– Analyse resource allocation

Evaluate the resources to ensure that the resources are not overall located.

– Analyse cost budget

Evaluate project costs.


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# 7 QC Tools

- Pareto Chart
- Check sheet
- Flowchart
- Histogram
- Scatter Chart
- Control Chart
- Cause and Effect Diagram


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# What is a Pareto Chart?

This is a chart that contains bars and a line graph where the line graph represents cumulative total of frequencies.

The bars represent individual frequencies of items like customer complaints etc.

It uses the 80-20 principle, as per which 80% problems happen due to 20% causes.

The chart helps you to prioritize between a whole list of problems resulting in it being used widely as a **Prioritization tool.**

| Complaint | Frequency |
|---|---|
| Wait time high | 100 |
| Service time high | 20 |
| Service quality poor | 15 |
| Price high | 15 |
| Supervisors rude | 10 |
| Solution not provided | 9 |
| Associates rude | 8 |
| Product didn't meet specs | 7 |


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## Step 1

Find out individual % contributions of each complaint and add up cumulative totals as shown below:

| Complaint | Frequency | Indiv % | Cumulative % |
|---|---|---|---|
| Wait time high | 100 | 54.35% | 54.35% |
| Service time high | 20 | 10.87% | 65.22% |
| Service quality poor | 15 | 8.15% | 73.37% |
| Price high | 15 | 8.15% | 81.52% |
| Supervisors rude | 10 | 5.43% | 86.96% |
| Solution not provided | 9 | 4.89% | 91.85% |
| Associates rude | 8 | 4.35% | 96.20% |
| Product didn't meet specs | 7 | 3.80% | 100.00% |
| Total | 184 | | |


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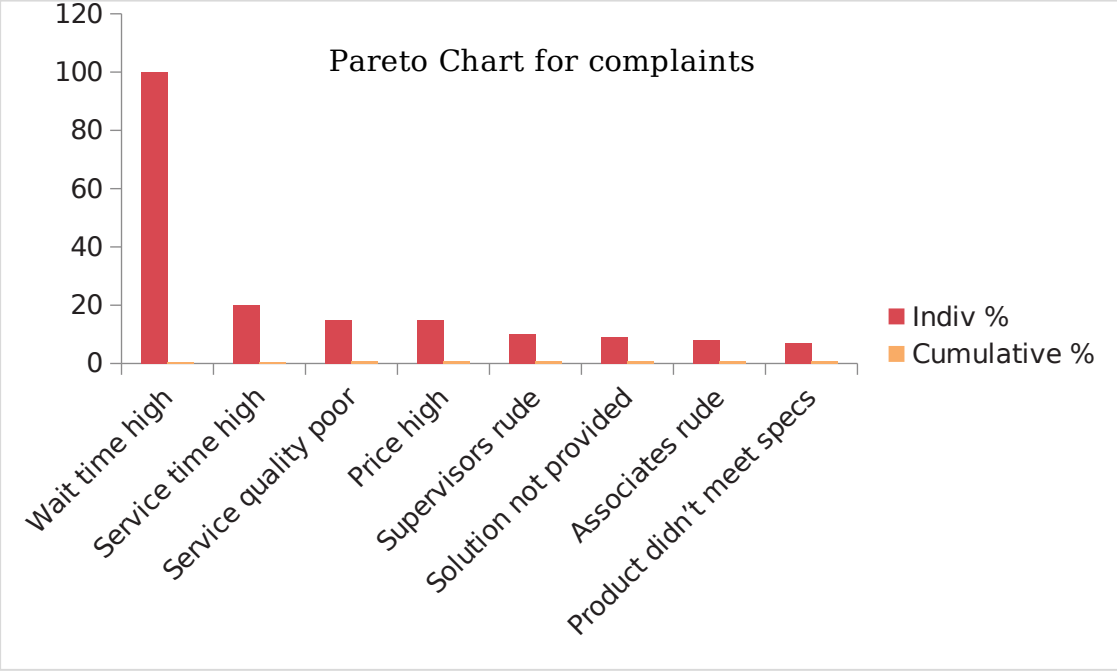
## Step 2

Hide the Indiv % column as we don’t need it to draw a Pareto Chart and select a 2-D Clustered Column Chart (Insert  Chart  2D Clustered Column Chart). The chart would appear like the one shown below:





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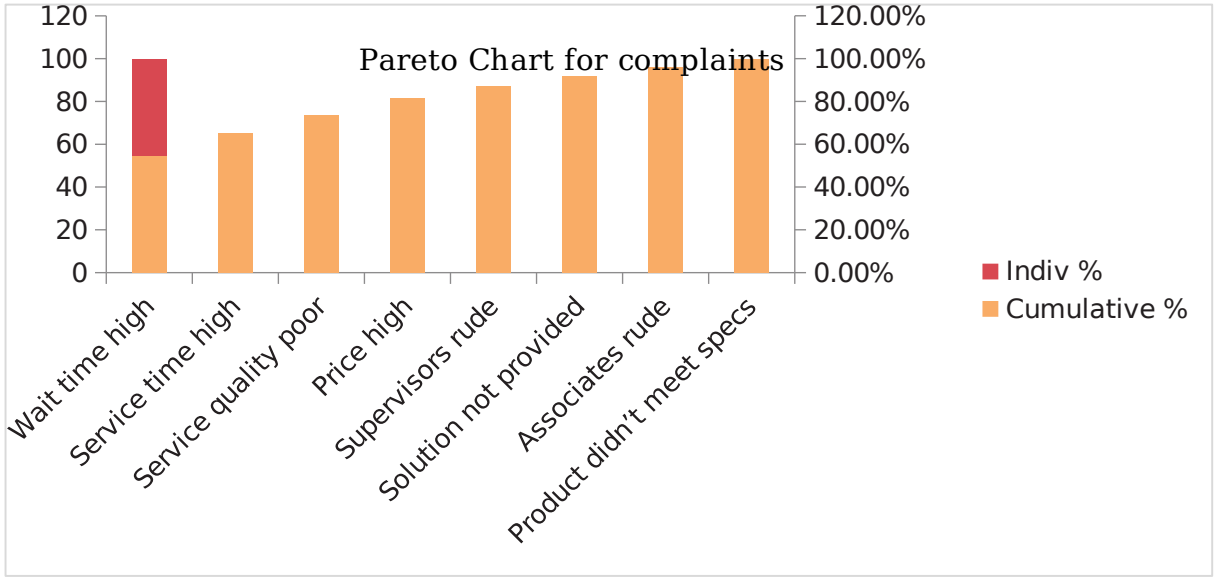
## Step 3

Double click on Cumulative %, and change the axis selection to Secondary Axis (Right Click  Format Data Series  Under Plot Series on, change the radio button to Secondary Axis).
The graph will look like:





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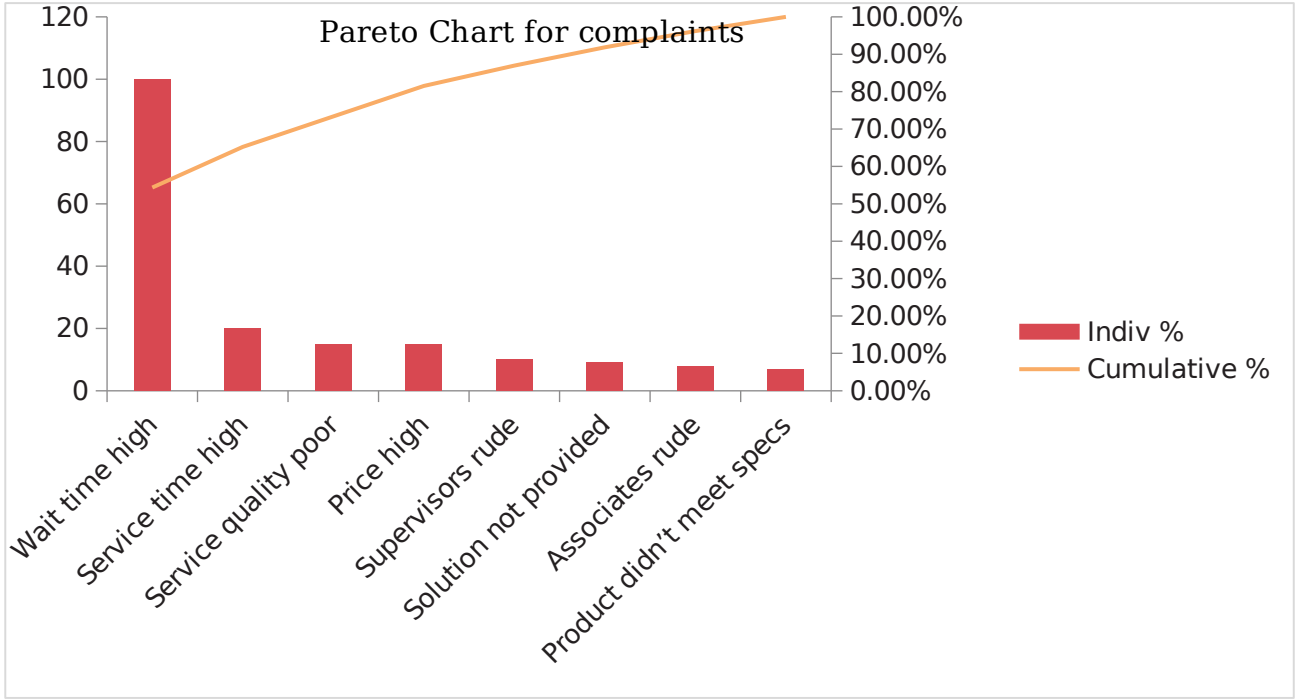
## Step 4

Now, right click on Cumulative %  Click on Change Series Chart Type  Select the first option under Line Chart.

The graph changes to:





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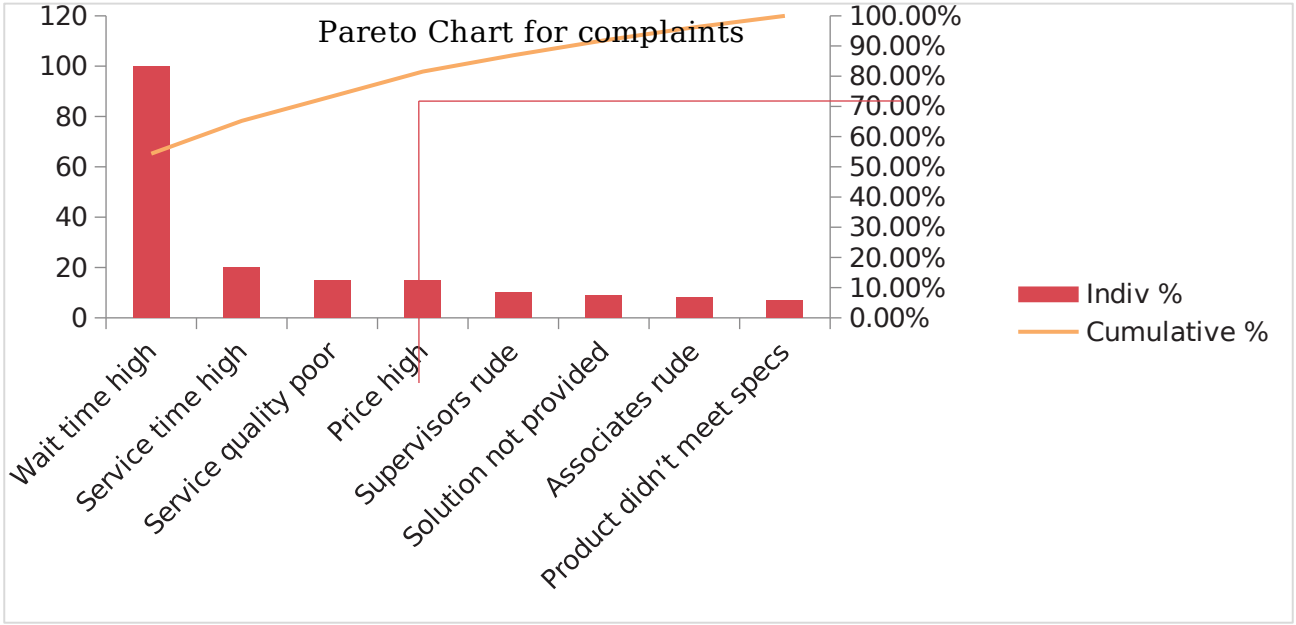
## Step 5 - Interpretation




80% of customer complaints are due to “Wait time high”, “Service time high” and “Service Quality Poor”.

The Operations team must look to fix these problems at the earliest with 20% being Vital Few.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# What are Check sheets?

Check sheets are simple data collection templates used in Six Sigma projects.

At a lot of times, companies may not have all the data needed for the project.

In such a scenario, the project team designs a check-sheet to capture additional information needed for the project.

Note: Companies may design their own check-sheets and thus, this template shown below, can differ

| Defect Types/ Event Occurrence | Dates | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | |
| Defect 1 | | | | | | | | |
| Defect 2 | | | | | | | | |
| Defect 3 | | | | | | | | |
| Defect 4 | | | | | | | | |
| Defect 5 | | | | | | | | |
| Defect 6 | | | | | | | | |
| Defect 7 | | | | | | | | |
| Defect 8 | | | | | | | | |
| Defect 9 | | | | | | | | |
| Defect 10 | | | | | | | | |
| TOTAL | | | | | | | | |


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# 7 QC Tools: Flow chart

## What are Flow charts?

Flow charts are considered to be basic “process mapping” tools.

Before any process is improved, one needs to know how it flows, what are its inputs etc.

Flow charts can be drawn at many levels – Macro level, Level 2 and Improvement level

A macro-level flow chart is done to showcase the process on how you see it from a bird’s eye view.

A Level 2 flow chart shows how the process actually happens. This is a bit more detailed than the Macro-level or Level 1 Map.

The Improvement level flowchart contains all the details you need to make informed decisions of your process and also to identify key pain-points.

The flowchart shows the way how your process is done to help converting the input to output desirable to the customers.


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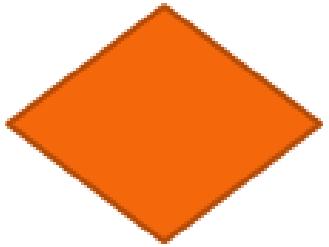
# 7 QC Tools: Flow chart

## Symbols

**Below are some of the popular flow chart symbols**

Process

Connector



Decision

Start/ End

Alternate process

Delay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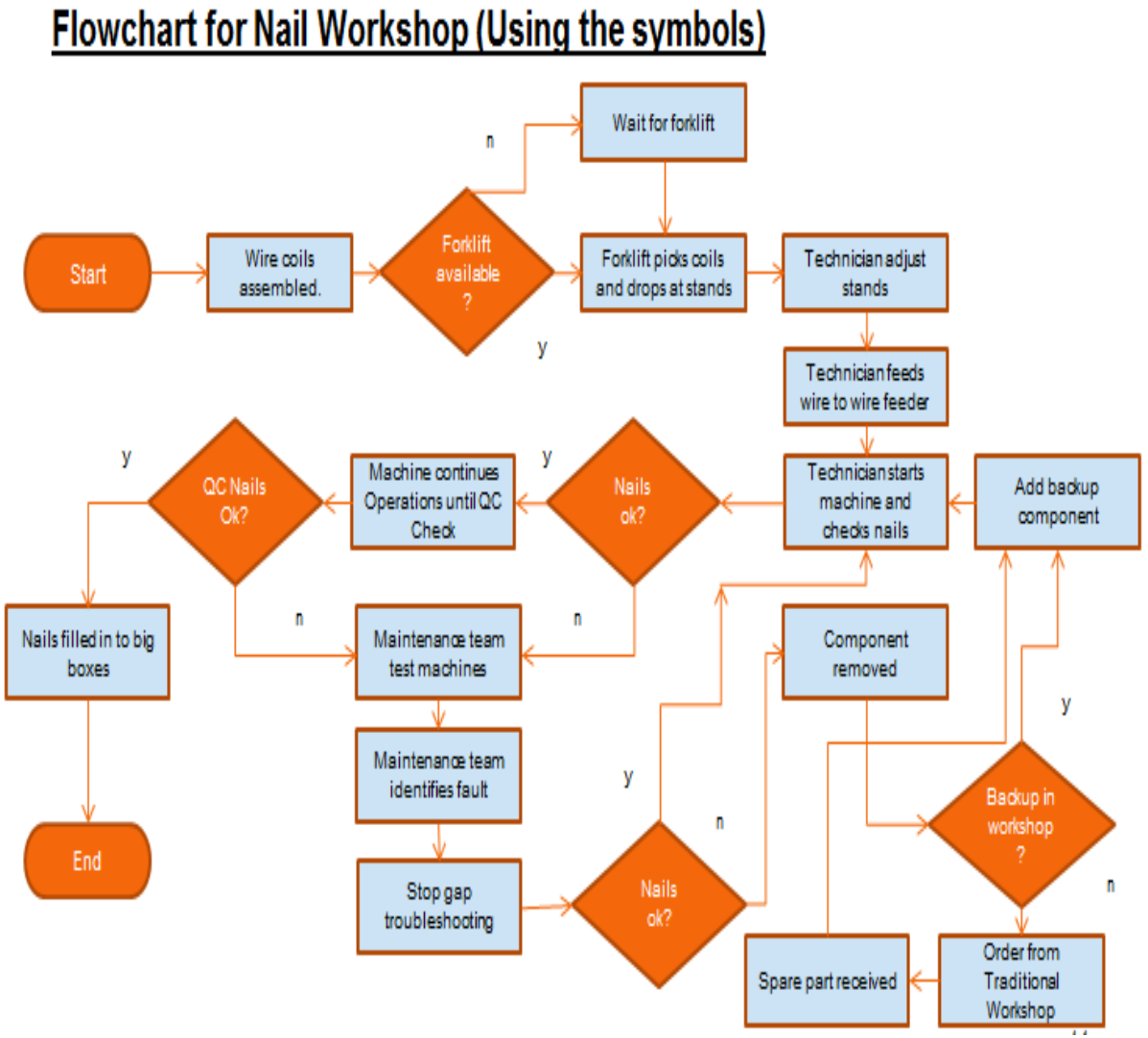
# 7 QC Tools: Flow chart




The flowchart has been prepared for a real life project scenario, where the project team wished to improve the machine capacity of a nail manufacturing workshop.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# What is a Histogram?

- After collecting data, the team would like to know what the data distribution is like.
- Understanding the data distribution is essential because it will help them take decisions on the entire process performance and not just on isolated points.
- A Histogram will help in giving an individual the understanding of his data distribution.
- It will also tell him if there are any possible special causes acting on

# How?

We shall use the Analysis Woolpack option in Excel although this can be done fairly easily using packages like Minitab.


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# 7 QC Tools: Histogram

**Data**

The data for histogram is as shown. This data is collected for wait times for a bank.

The team desiring to make an improvement to the wait times wants to see if the wait times are significantly higher in any of the bank branches or not.

To draw a histogram, the individual needs to know some definitions:

Quartile 1: 1st quartile (25%)

Quartile 3: 3rd quartile (75%)

| Sample 1 | Sample 2 | Sample 3 |
|---|---|---|
| 10.30 | 10.56 | 10.13 |
| 10.04 | 10.88 | 10.10 |
| 10.49 | 10.88 | 10.01 |
| 10.14 | 10.18 | 10.23 |
| 10.69 | 10.17 | 10.70 |
| 10.45 | 10.96 | 10.50 |
| 10.18 | 10.28 | 10.10 |
| 10.10 | 10.76 | 10.82 |
| 10.80 | 10.48 | 10.14 |
| 10.97 | 10.75 | 10.34 |
| 10.10 | 10.68 | 10.78 |
| 10.85 | 10.46 | 10.81 |
| 10.04 | 10.64 | 10.92 |
| 10.60 | 10.03 | 10.03 |
| 10.79 | 10.81 | 10.41 |
| 10.87 | 10.59 | 10.21 |
| 10.07 | | 10.92 |
| 10.88 | | 10.13 |
| 10.84 | | 10.44 |
| 10.47 | | 10.89 |
| 10.51 | | 10.67 |
| 10.69 | | 10.83 |
| 10.22 | | |


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# 7 QC Tools: Histogram

**Step 1**

Calculate Min, Max and Quartile values

| Descriptive stats | Data |
|---|---|
| Min | 10.01 |
| Max | 10.99 |
| Quartile 1 | 10.19196 |
| Quartile 3 | 10.82124 |

**Step 2**

Calculate the next measure of descriptive statistics: IQR. IQR stands for Interquartile range and is expressed as the difference between 3rd quartile and 1st quartile. Also write the count of the data set.

| Descriptive stats | Data |
|---|---|
| Min | 10.01 |
| Max | 10.99 |
| Quartile 1 | 10.19196 |
| Quartile 3 | 10.82124 |
| IQR | 0.629286 |
| Count | 49 |


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# 7 QC Tools: Histogram

**Step 3**

Every histogram is drawn on two important bits of information: **Bin size and Number of Bins**.

To calculate **Bin Size**, apply the Freedman Diaconis Rule:

**Bin Size** = 2 * IQR * (Count) $^{-1/3}$

Compute number of bins using the formula,

**Number of bins** = (max – min)/ Bin Size

Number of bins = 2.88 = 3

**Step 4**

Define the bins. Start with the minimum value as the first bin and keep adding the bin size until you reach 3 bins.

| Descriptive stats | Data |
|---|---|
| Min | 10.01 |
| Max | 10.99 |
| Quartile 1 | 10.19196 |
| Quartile 3 | 10.82124 |
| IQR | 0.629286 |
| Count | 49 |
| Bin Size | 0.344384 |
| Number of bins | 2.882353 |
| | |
| Bins | 10.01 |
| | 10.35 |
| | 10.69 |


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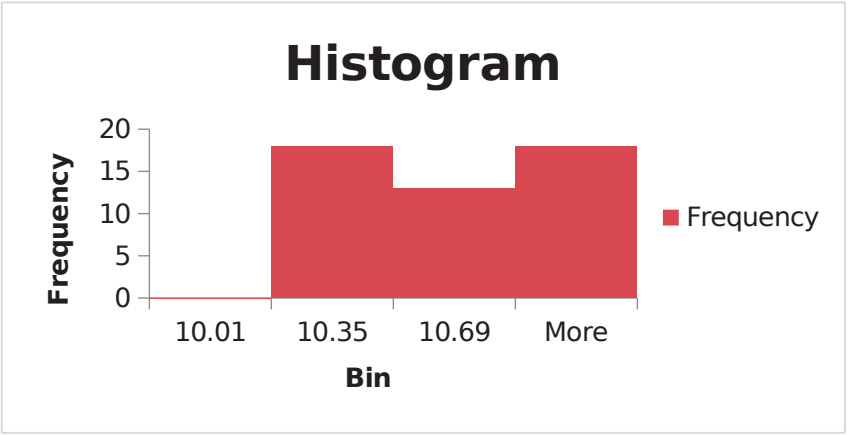
# 7 QC Tools: Histogram

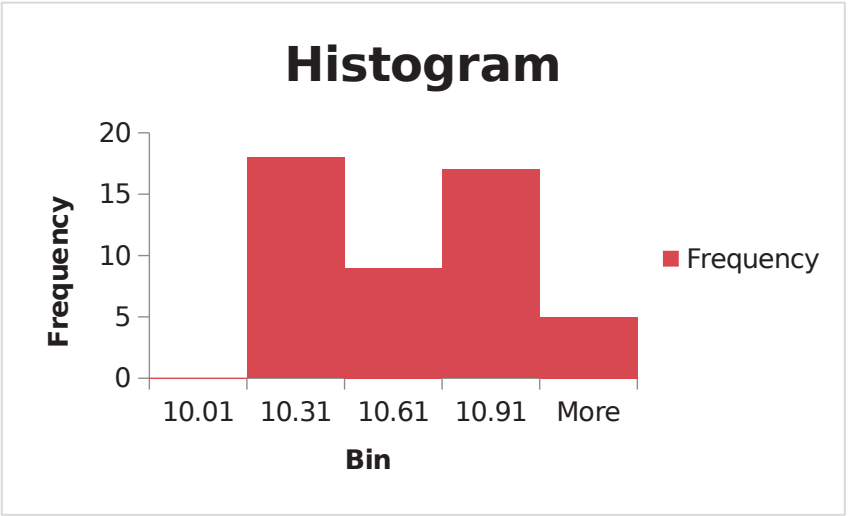
## Step 5

Use the Add-in tool provided in Microsoft Excel to draw the Histogram. The histogram here doesn't give an accurate picture, so the bin size and the number of bins need be changed to make it more granular.




## Step 6

Round down the bin size and round up the number of bins, and re-draw the histogram.





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# Step 7

## Inference

The data distribution doesn’t follow a normal distribution.

The data suffers from a possible bi-modality at 10.31 and 10.91.

It seems like the data has been collected from two sources.

If the project team wishes to reduce the wait time, it has to understand the best practices of the sample that delivers 10.31 and ensure they are cascaded.


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# What are Scatter Charts?

In a project done using Six Sigma approaches, there are two kinds of variables: KPOV (Key Process Output Variable) and KPIV (Key Process Input Variable).

Using Scatter Charts and an associated technique, Regression Analysis, an individual can determine the extent of statistical relationship between the two sets of variables.

As such, a scatter chart is known as “Relationship determination tool”.

To draw scatter charts, you would need pairwise and continuous data.


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# 7 QC Tools: Scatter Charts

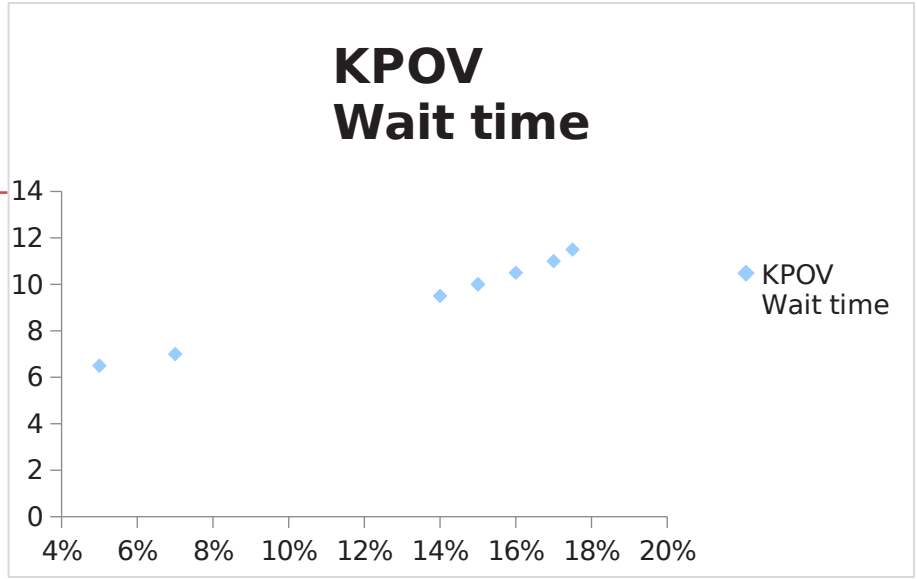
## Data

The data is collected for both KPIV and KPOV and  the data table is as shown:

| KPIV Absenteeism % | KPOV Wait time |
|---|---|
| 15% | 10 |
| 16% | 10.5 |
| 17% | 11 |
| 17.50% | 11.5 |
| 5% | 6.5 |
| 15% | 10 |
| 14% | 9.5 |
| 7% | 7 |

## Step 1

Click on Insert  Scatter Chart  Choose the first chart, Scatter with markers. The graph would be as below:





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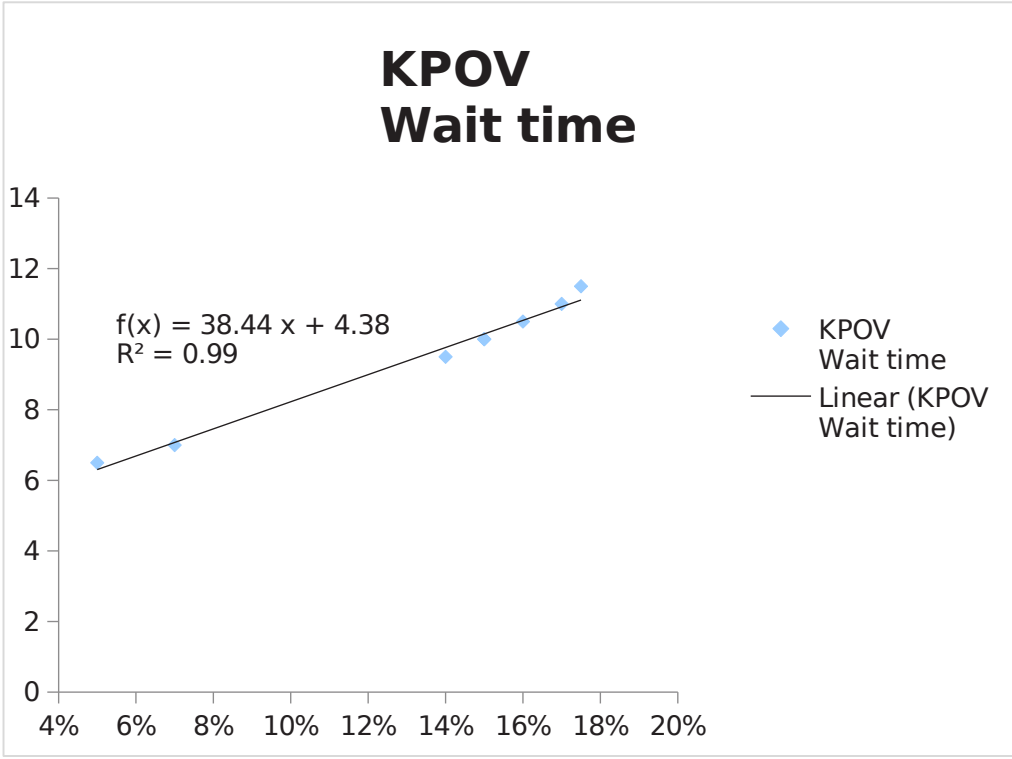
# 7 QC Tools: Scatter Charts

## Step 2

Click on any point in the graph  Right Click and choose Add Trendline  Select Linear  Select “Display R-Square value” and “Display Equation”.

The R2 value and the equation mentioned on top of the line is an auto-calculated feature from Excel. A statistical formula will help in calculation of these metrics manually, which will be explained in the Green Belt or Black Belt Body of Knowledge.





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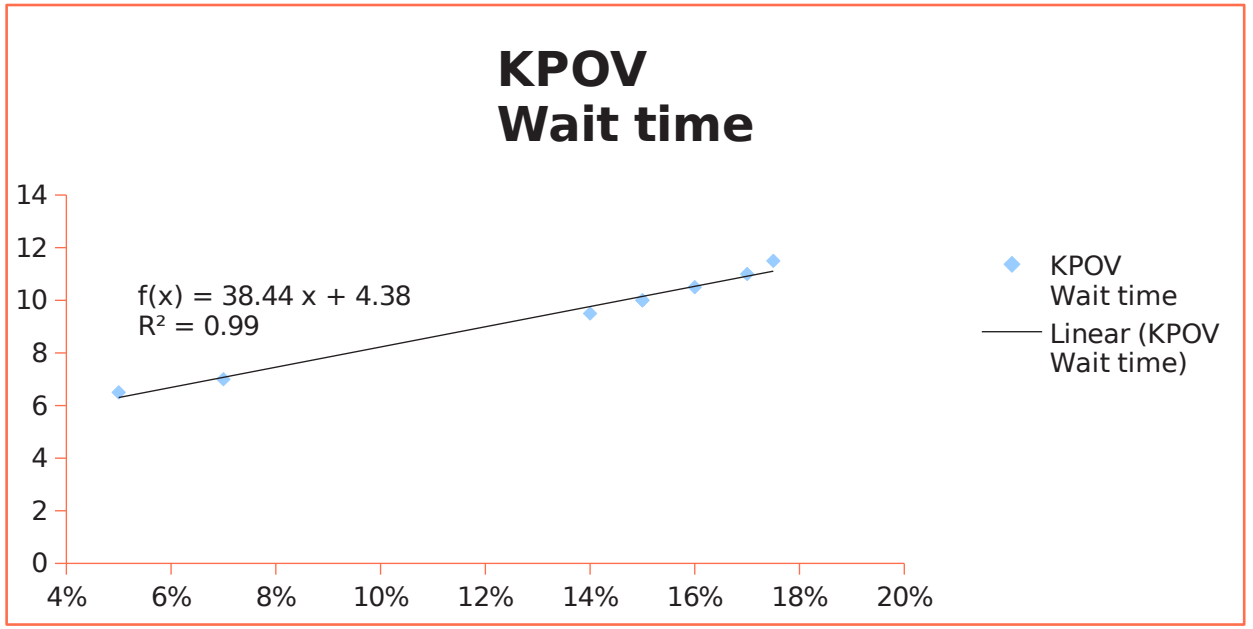
# 7 QC Tools: Scatter Charts




## Interpretation

R-Square value is 0.9882, i.e. Coefficient of Determination is 98.82%. This means that 98.82% variability in Wait time is explained by absenteeism.

If the R-Square value > 64%, you can use the Regression Equation to find optimal value of Absenteeism that would give the ideal value of Wait time.

**For example, for Wait time to 8 minutes, the absenteeism rate should be 9.4%.**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# What are Control Charts?

Control Charts are known as Process Behavior Charts.

Project teams use control charts to know if the process is behaving under the influence of special causes of variation.

Choice of control charts is important because a wrong selection of control charts will give you wrong inference for the data.

Special causes of variation get highlighted when any data point crosses the 3 Sigma limits from the mean.

The 3 Sigma limits are known as Control Limits. Every control chart would have 2 Control limits, known as Upper Control Limit and Lower Control Limit.

The project team has the choice of fixing the control limits if they wish so. As a best practice, project teams are instructed to let the process data decide the control limits.


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# 7 QC Tools: Control Charts

**What?**

- The table below shows which control chart should be chosen when:

| Data type | Name of chart | Conditions |
|---|---|---|
| Continuous | I – MR | Subgroup size = 1 |
| | X Bar – R | Subgroup size 2 - 8 |
| | X Bar – S | Subgroup size 8 - 15 |
| Discrete | P | Defectives, varying sample size |
| | Np | Defectives, varying sample size |
| | U | Defects, varying sample size |
| | C | Defects, constant sample size |


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# 7 QC Tools: Cause and Effect Diagram

## What is a Cause and Effect Diagram?

A Cause and Effect Diagram is a quality tool that helps the project team understand the possible causes to an event.

This tool was first popularized by Dr. Kaoro Ishikawa.

The causes are grouped under logical categories like 6M, 7P, 5S etc.

The causes to the event first need to be arrived at by brainstorming.

The project team then arranges these causes into the logical categories, as deemed fit.

The criticism about Cause and Effect Diagram is that it serves as a good visual representation to the causes for an event. There is no statistical validation of any of the causes unless the team decides to support the causes with data, which is outside the realms of the Cause and Effect Diagram.


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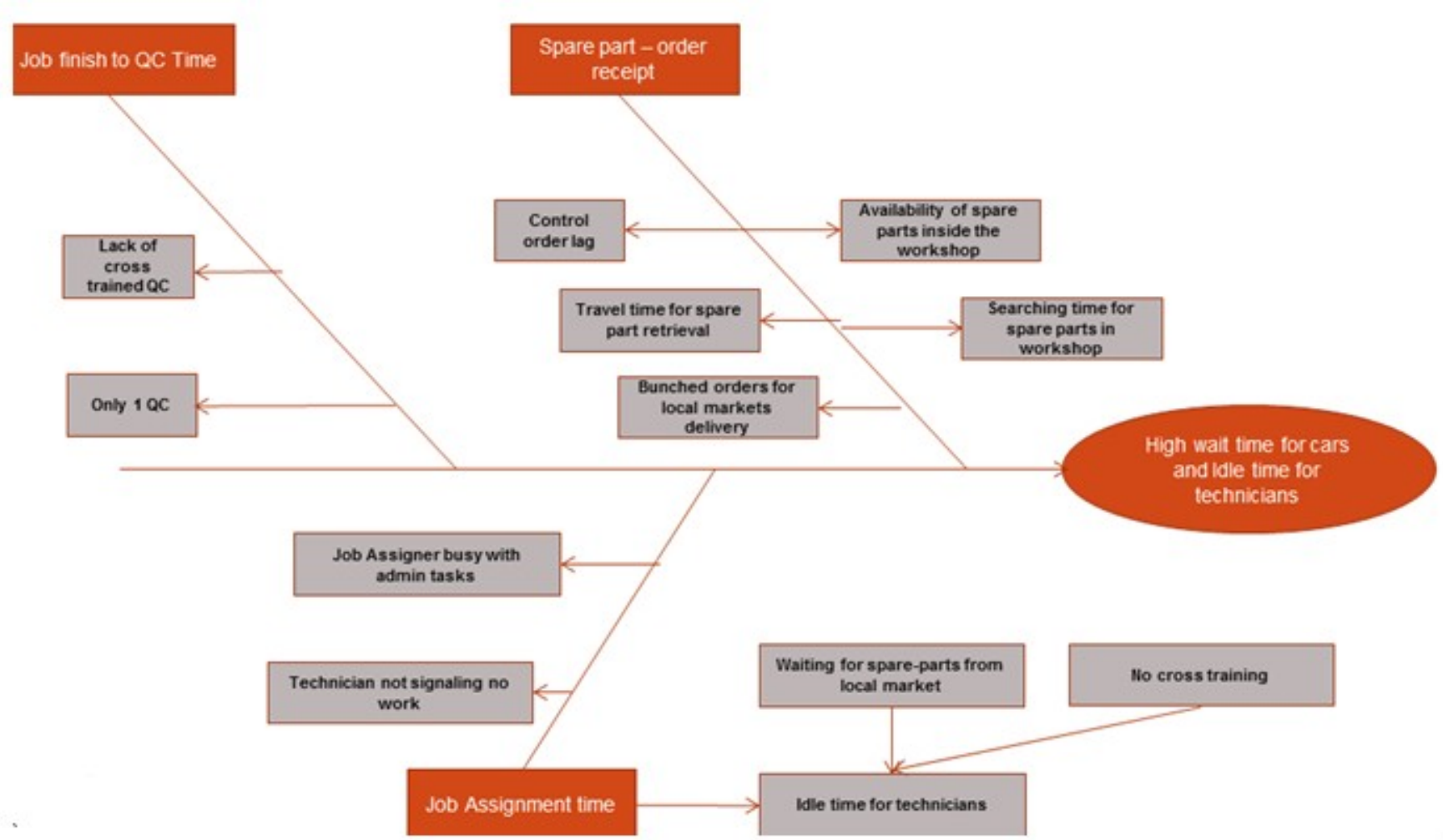
# An example of Cause and Effect Diagram


Job finish to QC Time
Spare part – order receipt
Control order lag
Availability of spare parts inside the workshop
Lack of cross trained QC
Travel time for spare part retrieval
Searching time for spare parts in workshop
Only 1 QC
Bunched orders for local markets delivery
High wait time for cars and Idle time for technicians
Job Assigner busy with admin tasks
Technician not signaling no work
Waiting for spare-parts from local market
No cross training
Job Assignment time
Idle time for technicians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# 7 QC Tools: Summary

Pareto Charts are popularly used as a prioritization tool to identify the top 20% reasons that contribute to 80% customer complaints.

A Check Sheet helps you to collect data in the absence of automated reporting procedures.

Flow charts help you to map the process steps.

A Histogram helps you to understand the shape and the data distribution.

Scatter Charts help in statistically validating relationships between input and output variables.

Control Charts help in identifying if the process behaves under the influence of special causes of variation.

A Cause and Effect Diagram will logically group the causes that result in a particular event.


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# Module 5

# Introduction to Improve


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# Improve Phase

**Key Objective:** Validated Solutions

**Key Deliverables:** Potential solutions, FMEA, Risk Assessment, Pilot Plan

| | |
|---|---|
| **Roadmap of the Improve Phase:** | Develop Potential Solutions: Based on the validated & prioritized root causes, develop potential solutions |
| | Prioritize Best Solutions: Prepare a criteria and prioritize best solutions which works best in business interest |
| | Evaluate Risk: Assess risk in implementation of each solution |
| | Pilot Plan: Prepare a pilot plan for implementation of best solutions |
| | Toll Gate Review: Toll gate review to be conducted with Sponsor, Black Belt & Project leader |


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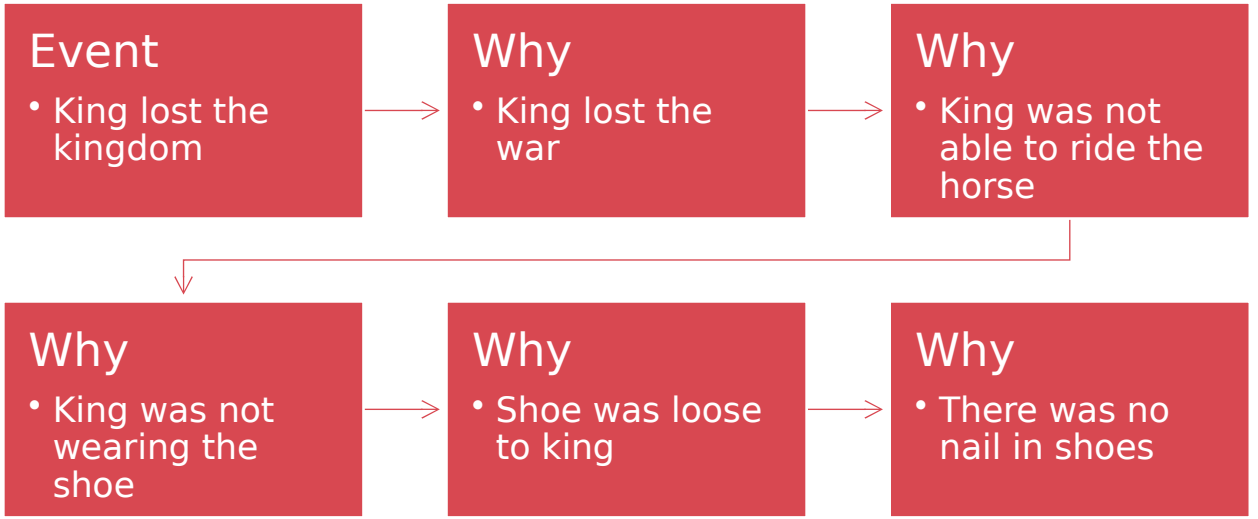
# Why – Why Analysis

1. Explore the root cause of the issue by asking "why" multiple times to uncover the underlying reasons.

2. Identify patterns or trends that may contribute to the problem through in-depth analysis.

3. Consider alternative perspectives and seek input from others to gain a comprehensive understanding.

4. Use the "5 Whys" technique to systematically investigate the causes and effects of the situation.




| Event | Root Cause | Actionable | Action Plan | Success Criteria | Responsible | Timeline |
|---|---|---|---|---|---|---|
| King lost the kingdom | There was no nail in shoes | Nail should always be intact on shoe | Cobbler and Minister will ocheck the shoe fitment everytime before king goes for horse ride. | Ifking has not complaint about shoe fitment atleast 1 mile of the horse ride | Cobbler and Minister | 30-Aug-24 |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# Improvement Plan

| Event | Root Cause | Actionable | Action Plan | Success Criteria | Responsible | Timeline |
|---|---|---|---|---|---|---|
| King lost the kingdom | There was no nail in shoes | Nail should always be intact on shoe | Cobbler and Minister will check the shoe fitment every time before king goes for horse ride. | Ifking has not complaint about shoe fitment atleast 1 mile of the horse ride | Cobbler and Minister | 30-Aug-24 |


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The idea is to produce zero defects by utilizing quality tools which prevent human errors. Combining Poka Yoke with Six Sigma helps to achieve precisely that.

# What is Poka Yoke?

Poka-yoke was developed in the 1960s at Toyota by one of their industrial engineers, Shigeo Shingo.

Shingo had also coined the idea of producing zero defective items using Poka Yoke, which are small tools that can help prevent the defects from occurring in the first place. This helps companies achieve zero defects in a very simple manner.

The simplicity of Poka Yoke is due to its ability of being created by any employee, may it be a manager, sales assistant or any other employee of the organization who sees the need and has the idea to do it.


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# How to Mistake-Proof a Process?

Mistake proofing requires employees to be alert. Primarily, an employee actually working on a product is in a better position to notice mistakes in the process.

If they are aware of the processes, they can come up with ways to overcome errors. This can encourage employees to come up with timely rectifications without delay, which can bring about greater results.

Poka Yoke is useful everywhere and anywhere where there is a chance of something going wrong. For example, process operations is an area where there is chance of missing a step.


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## Using Poka Yoke

You may undertake a Pareto analysis first to identify operations where there is a high probability of errors.

The approach to mistake proofing can be procedural, mechanical, electrical, human or any other form of prevention.

Having a checklist to ensure all steps are undertaken in a sequence can help. You should test the mistake-proofing device and ensure that the user is also aware and trained to use and review it to achieve zero defects.

Error elimination need not be a complicated process. There are simple solutions to small mistakes which can otherwise mean disaster for the product. Combines with Six Sigma, mistake-proofing ensures elimination of defects in the first place.


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# Piloting Solution

It is possible to pilot all or some of every solution or new design that an organization wants to implement. And it is almost always worth the extra effort to pilot especially if conducting a DFSS (design for Six Sigma) project.

**Defining Pilot- from a Six Sigma viewpoint a pilot can be defined as:**

Testing the functional and sigma capabilities of the new process, where critical functions defined in the current generation of the multi-generational plan are operational but on a limited scale.

**Four primary advantages and/or objectives of utilizing a pilot are:**

- Limit capital and other resource expenditures (managing risk)
- Assess true performance of design and/or solutions in a controlled but “live” environment
- Identify additional improvements
- Identify implementation tips and traps


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# Why Pilot ?

There are numerous reasons to pilot:

- Confirm expected results and relationships
- Increase buy-in
- Improve the implementation
- Lower the risk of failure
- Improve the ability to better predict
- Monetary savings from a proposed solution
- Increase opportunities for feedback
- Quickly deliver a version of a solution to a particular segment
- Validate the measurement system
- Understand expected variation in the process and its possible impact to the customer
- Improve on solution


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# Piloting Solution (Continued)

## When to Pilot

In general, there is a way to pilot all or some part of every solution or new design that an organization wants to implement. It is almost always worth the extra effort to pilot. Consider doing a pilot when:

The scope of the design is large,

The new product/service could cause far-reaching, unintended consequences,

Implementing the design and/or solutions will be a costly process, and

The design and/or solutions would be difficult to reverse.

If conducting a DFSS (Design for Six Sigma) project, as opposed to a DMAIC (Define, Measure, Analyze, Improve, Control) project, piloting is almost always a must.


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# Piloting Solution (Continued)

| | |
|---|---|
| **Pilot Key Considerations** | Determining how long a pilot should run and how many samples are necessary are important considerations to be certain enough evidence is collected. Project leaders also need to be confident that the process is stable with regard to its performance over time. If the process is not stable the process capability (the ability to meet your customer requirements) cannot be assessed. |
| | Evaluate the measurement system first since it is imperative that the data collected is accurate and precise. Then assess the stability of the process prior to evaluating the capability. Lastly, review the scorecards. |


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# Piloting Solution (Continued)

## Verify the Implementation Plan

After the pilot, verify the implementation plan. Obtain assistance from the team and the process owners. These resources can help answer questions such as: Was your schedule met? Were the instructions clear? Were they followed? What additional information did people need? Were there unexpected challenges encountered?

## Pilot Verification and Validation

Once the implementation plan has been verified, verify and validate the pilot itself. Analyze gaps between predicted and test performance and pilot results. Analyze gaps between pilot results and actual requirements. And also analyze the actual pilot project plan; how did things come together? Did the design of the scorecards predict capability of the overall process and elements? For the gaps identified, perform a root cause analysis to determine “why.”


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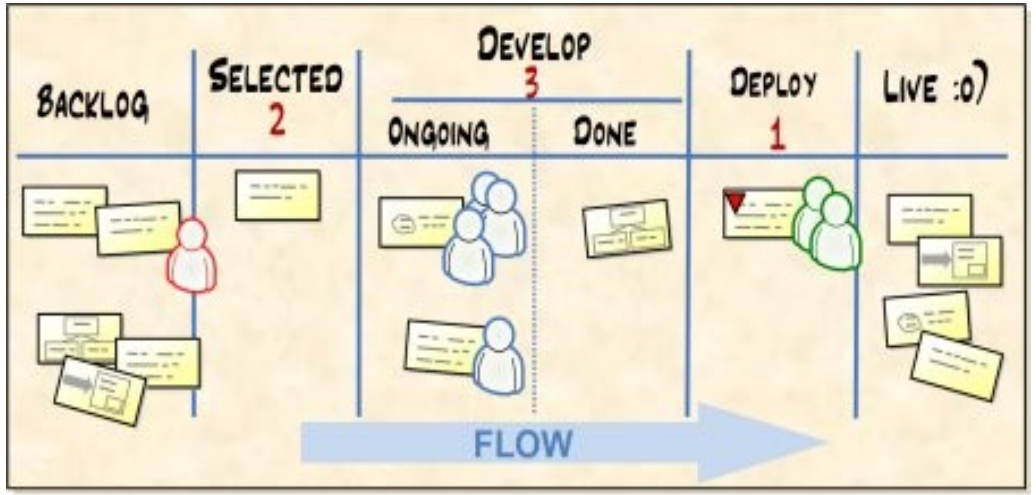
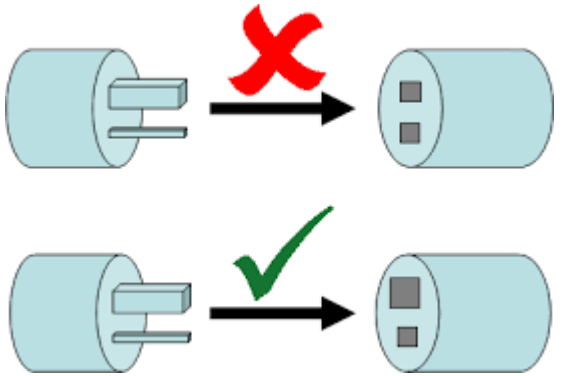
# Kanban and Poka-Yoke




Kanban



Poka-Yoke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# Elements of Waste – Lean

Transportation

Inventory

Motion

Waiting

Overproduction

Over processing

Defects

Skills

Defects
Efforts caused by rework, scrap, and incorrect information.
Overproduction
Production that is more than needed or before it is needed.
Waiting
Wasted time waiting for the next step in a process.
Non-Utilized Talent
Underutilizing people's talents, skills, & knowledge.
Transportation
Unnecesary movements of products & materials.
Inventory
Excess products and materials being processed.
Motion
Unnecessary movements by people (e.g. walking).
Extra-Processing
More work or higher quality than is required by the customer.


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## Module 6

# Introduction to Control & Project Closure


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| | |
|---|---|
| **Key Objective:** | Control Plan |
| **Key Deliverables:** | Control Plan, SOP, Project Sign off |
| **Roadmap of the Control Phase:** | Develop Control Plan: Develop control plans for process monitoring with implemented solutions |
| | Develop SOPs: Develop SOPs to train employees on new process |
| | Toll Gate Review: Toll gate review to be conducted with Sponsor, Black Belt & Project leader |
| | Project Closure: Calculate the realized benefits & close the project after a formal sign off by Sponsor |


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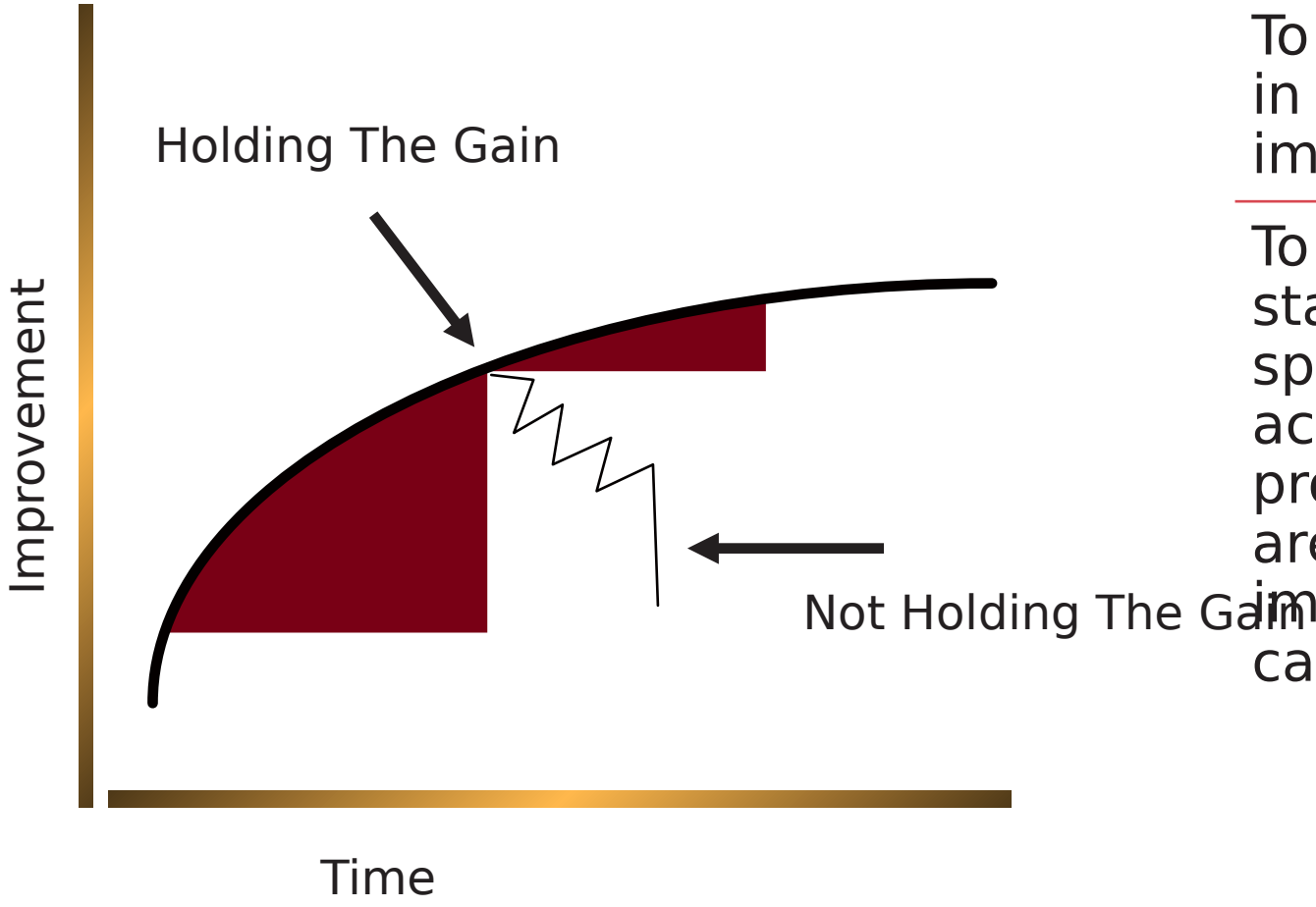
# Why Control?




To make sure that our process stays in control after the solution has been implemented

To quickly detect the out-of-control state and determine the associated special causes so that appropriate actions can be taken to correct the problem before non-conformances are produced, or to incorporate improvements based on the special cause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# How to Control?

By keeping the X’s within tolerance by using appropriate Control  tools (like FMEA, Mistake proofing,  etc.)

By applying Control charts to X’s to monitor and Control the variation

By understanding implications on existing Quality plans due to modification of current Control systems

By establishing Transition plan for maintaining Control of improved Process


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# Control Plans Answer the Following Questions

What is the process that is being controlled?

What is (are) the process output(s) that are being monitored/controlled?

What are the inputs that are being monitored/controlled in order to keep the output at its target level?

How are the inputs and outputs being measured, monitored, and controlled?

How does someone react when the inputs or outputs are not in control?


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# What is a Process Control System?

## A Process Control System (PCS)

strategy for maintaining the improved process performance over time

identifies the specific actions and tools required for sustaining the process improvements or gains

## A control system may incorporate

- Risk Management
- Mistake-proofing devices
- Statistical process control (SPC)
- Data collection plans
- Ongoing measurements
- Audit plans
- Response plans
- Product drawings
- Process documentation
- Process ownership


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# Key Steps in Developing a PCS

Complete an implementation plan.

- Plan and implement the solution and develop a method to control each vital X or key sources of variation
- Define all possible areas that may require action in order to control the process X and then determine the appropriate course of action to take

Develop a data collection plan to confirm that your solution meets your improvement goals.

- Establish ongoing measurements needed for the project Y and create a response plan to follow in case process performance falls below established standards

Communicate your strategy.

- Document the process and control plan to ensure process standardization and the continuation of the solution's benefits

Train Personnel.

Run the new process and collect the data to confirm your solution.


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# Process Interruption

***Process Interruption:***

Mechanism installed that shuts down the process and prevents further operation until a required action is preformed:

Ground fault circuit breakers

Child proof caps on medications

Software routines to prevent undesirable commands

Safety interlocks on equipment such as light curtains, dual palm buttons, ram blocks

Transfer system guides or fixtures that prevent over or undersized parts from proceeding

Temperature conveyor interlocks on ovens

Missing component detection that stops the process when triggered


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# Mistake Proofing

***Mistake Proofing*** is best defined as:

- Using wisdom, ingenuity, or serendipity to create devices allowing a 100% defect free step 100% of the time

Poka-Yoke is the Japanese term for mistake proofing or to avoid “yokeuro” inadvertent errors “poka”.

**See if you can find the Poka-Yokes!**


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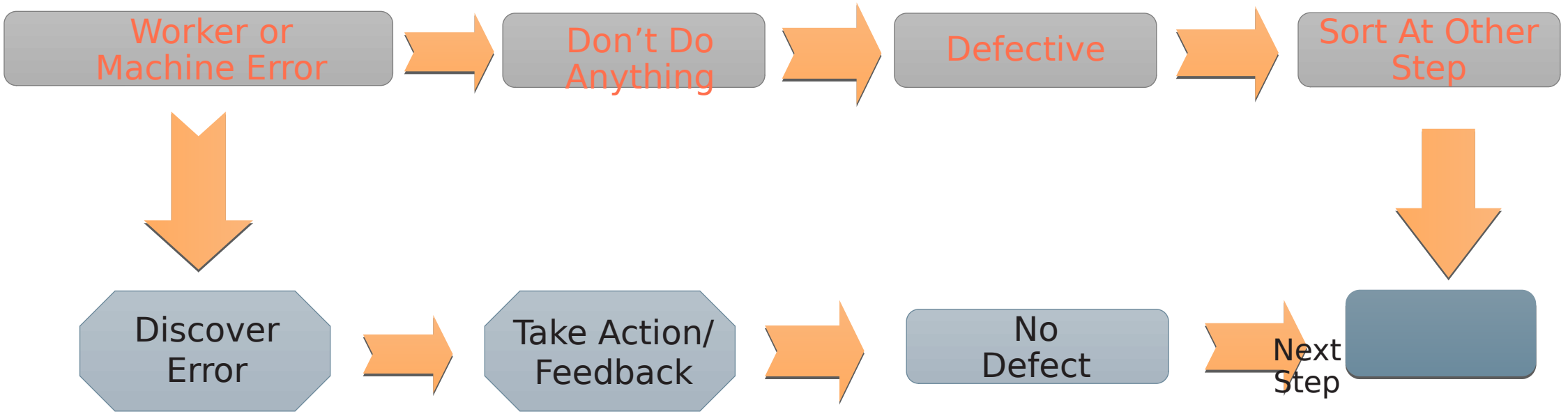
# Traditional Quality vs. Mistake Proofing

## *Traditional Inspection Result*




## *Source Inspection*

***"KEEP ERRORS FROM TURNING INTO DEFECTS"***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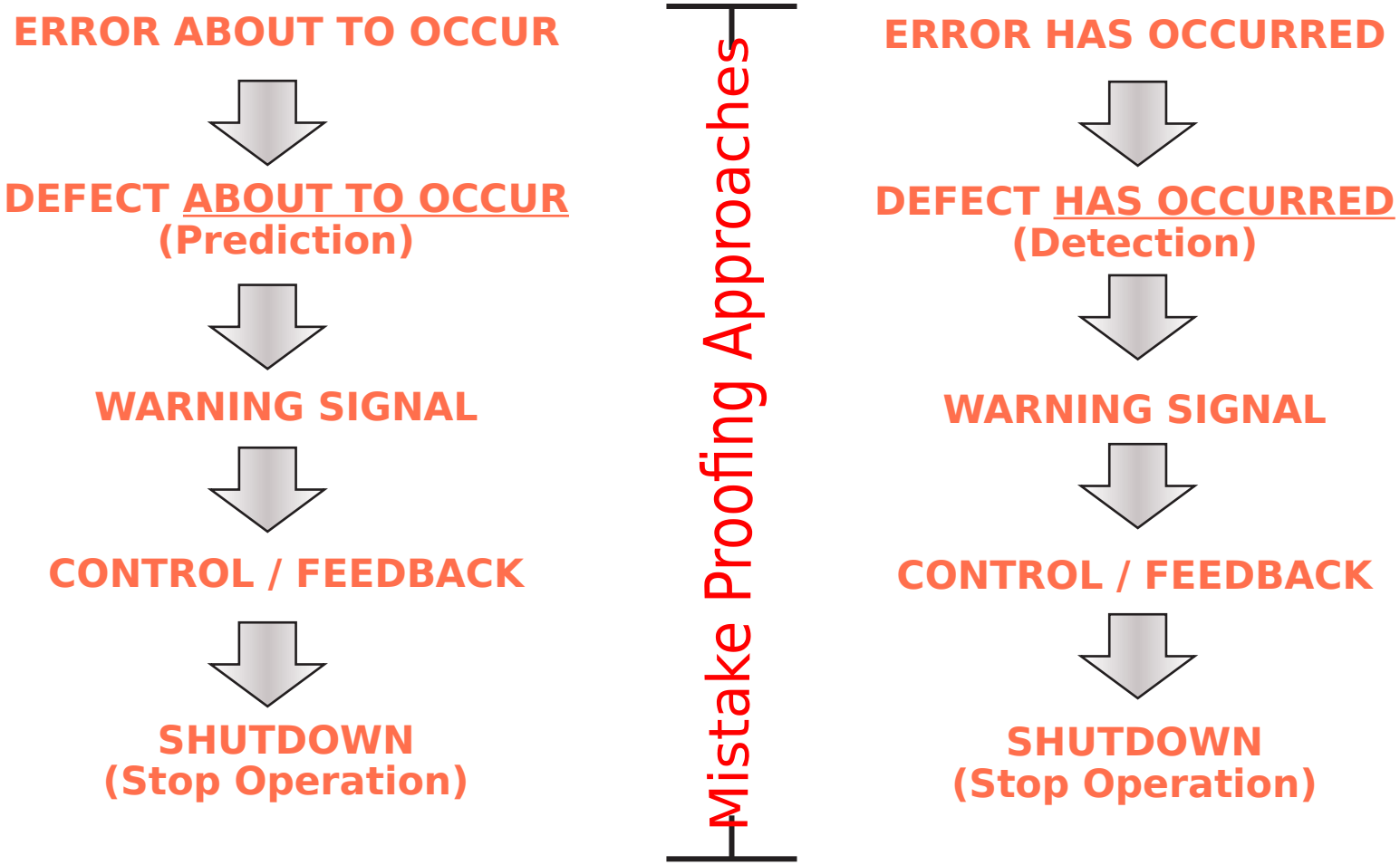
# Styles of Mistake Proofing

There are 2 states of a defect which are addressed with mistake proofing.





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# Advantages of Mistake Proofing as A Control Method

## Mistake Proofing advantages include:

- Only simple training programs are required
- Inspection operations are eliminated and the process is simplified
- Relieves operators from repetitive tasks of typical visual inspection
- Promotes creativity and value adding activities
- Results in defect free work
- Requires immediate action when problems arise
- Provides 100% inspection internal to the operation


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# Defect Prevention Culture and Good Control Plans

Involve everyone in defect prevention

- Establish process capability through SPC
- Establish and adhere to standard procedures
- Make daily improvements
- Invent Mistake-proofing devices

Make immediate feedback and action part of culture

Don’t just stop at one mistake proofing device per product

Defect Prevention is needed for all potential defects

Defect Prevention implemented MUST be documented in your living FMEA for the process/product


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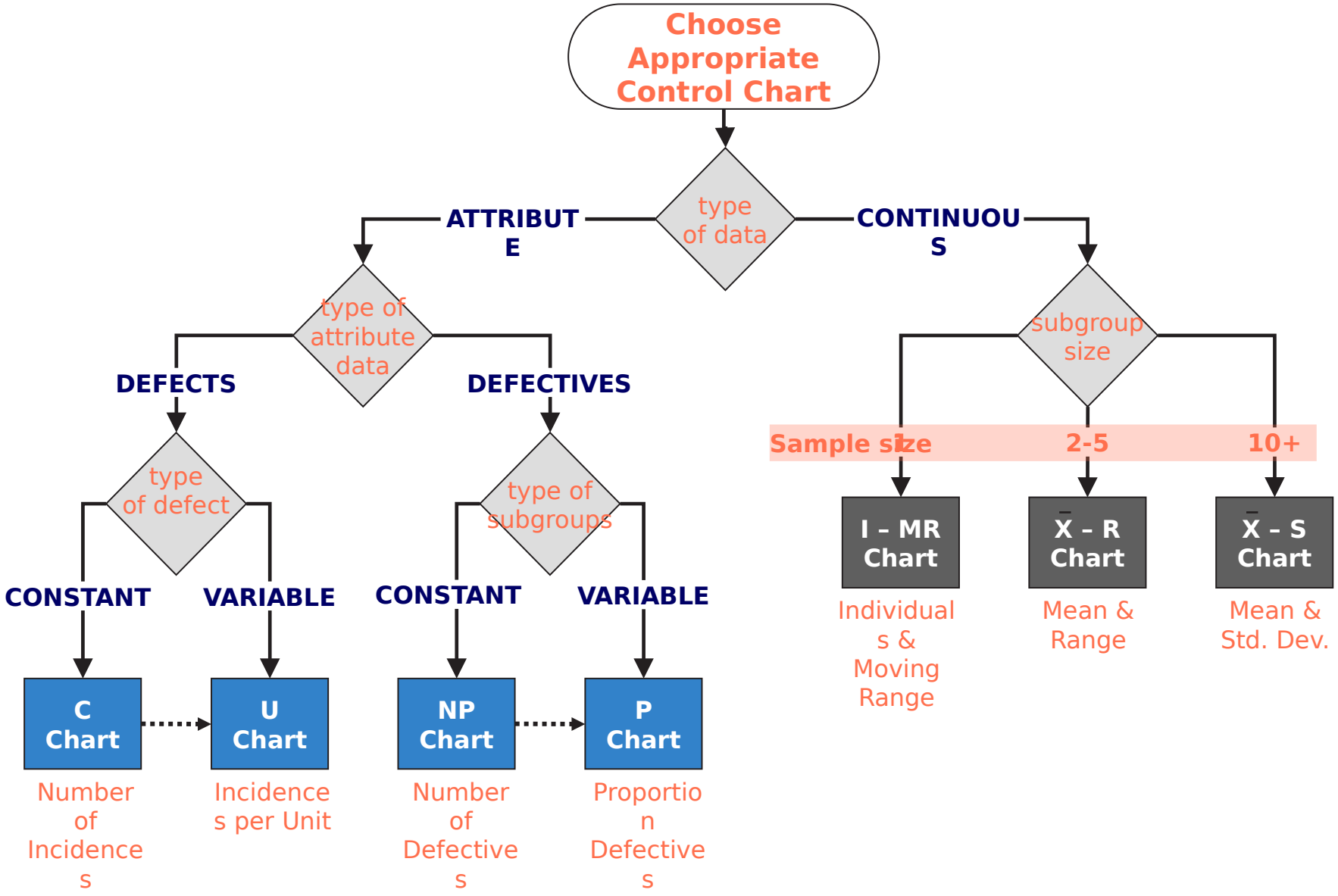
# Control Charts Selection Process





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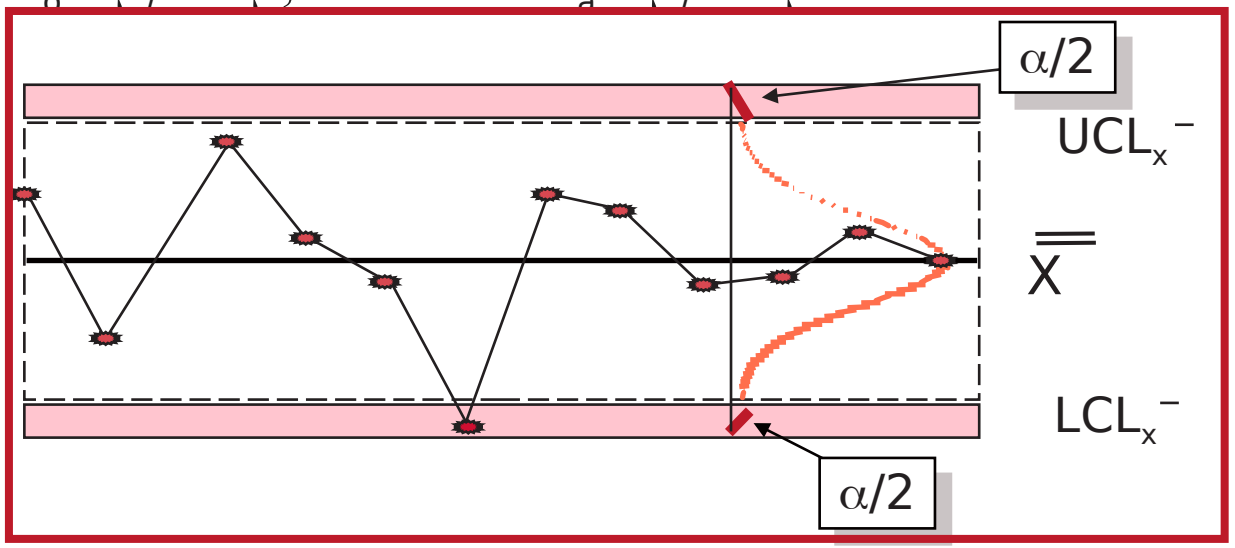
A Control Chart is a graphic display of a continuing two tailed test with $H_O$ and $H_A$ defined as:

$H_o: \mu_i = \mu$; $H_a: \mu_i \neq \mu$




For 3s limits, a/2 = 0.00135. approximate confidence level is 99.7%.

3 s limits provide good sensitivity to change with low potential for over-reacting when the process is stable.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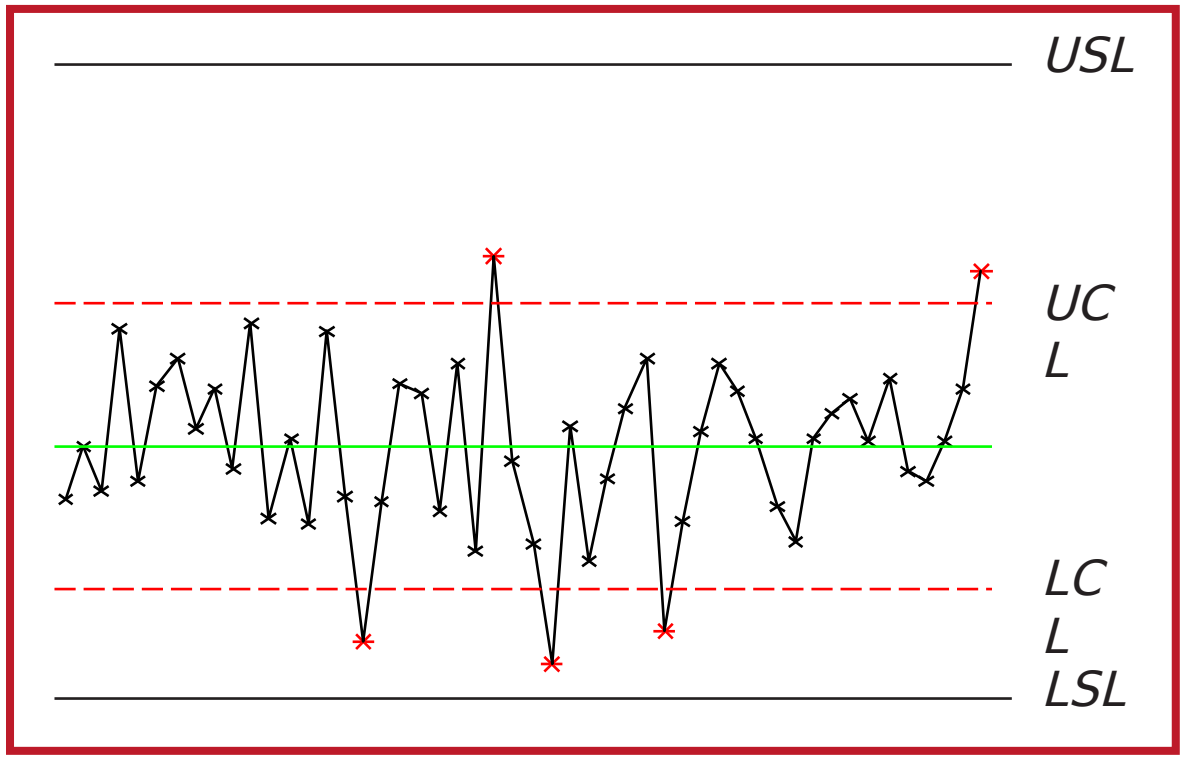
# Control Limits Vs Specification Limits




Control limits are determined by process variation *(Voice of Process)*

Specification limits are determined by customer needs *(Voice of Customer)*

Control limits are *for averages*, not individual values. Most specifications are for *individual values*.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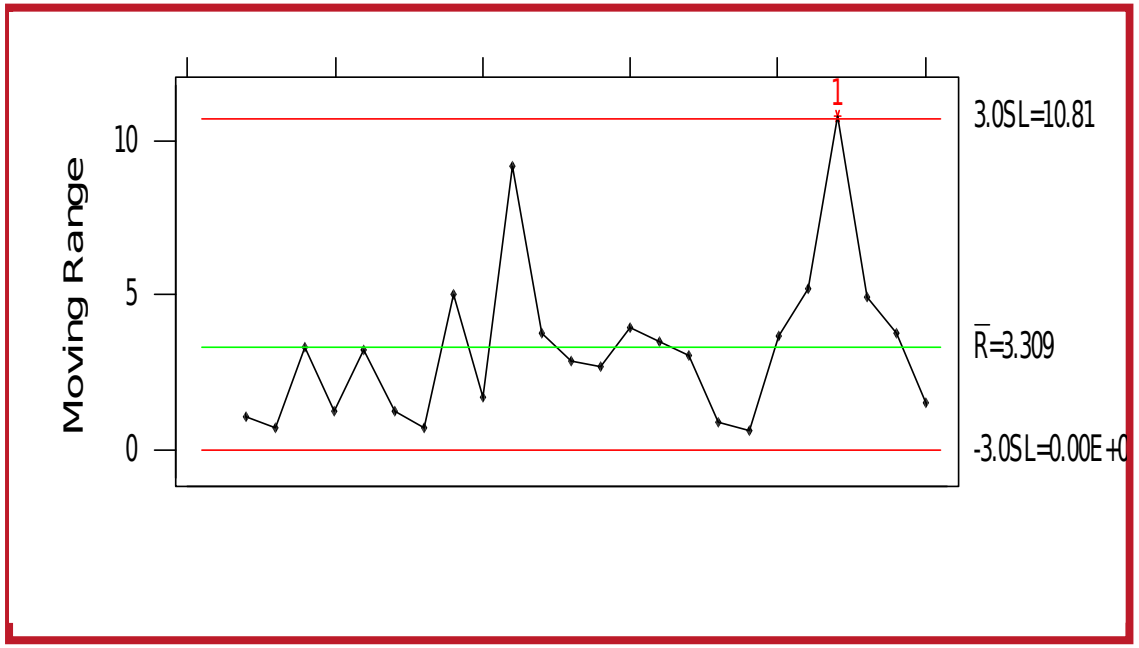
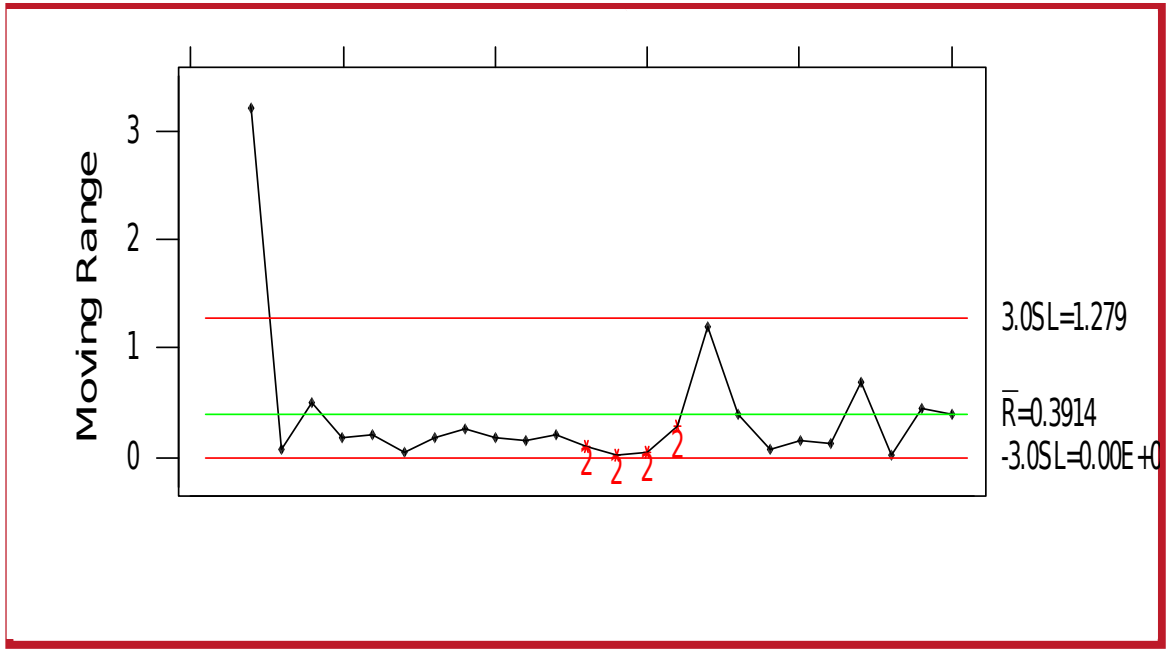
# Special Cause - Rules




Rule1

One point more than 3SD from center line




Rule2

Nine points in a row on same side of center line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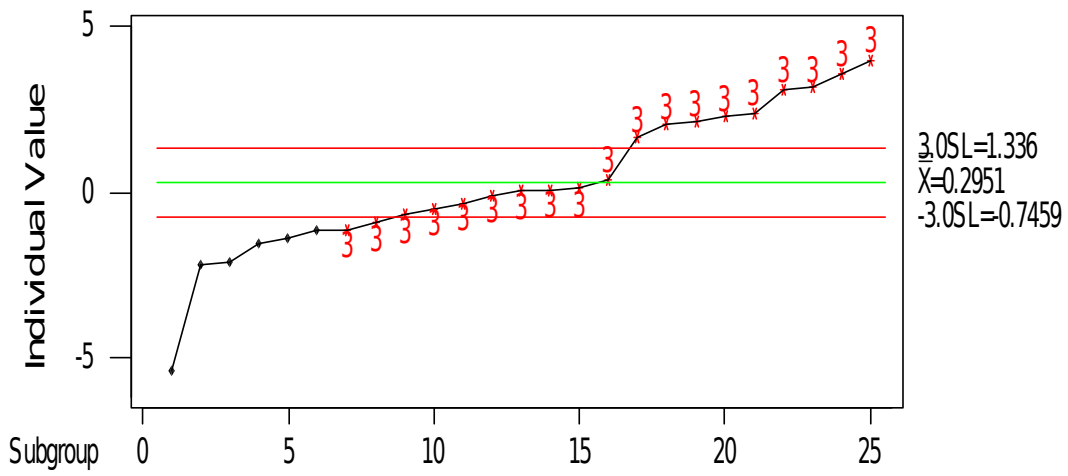
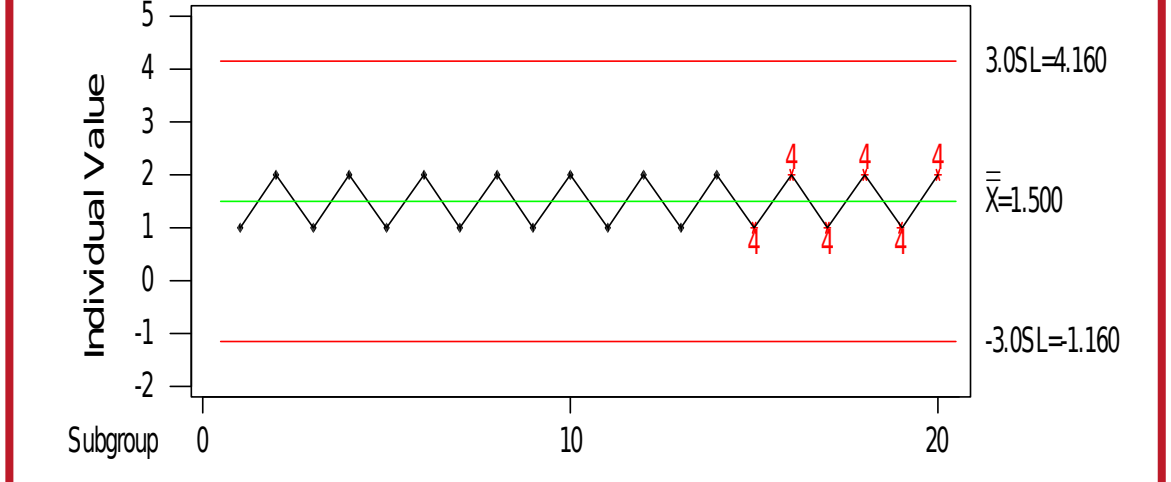
# Special Cause - Rules




Rule3

Six points in a row all increasing or all decreasing




Rule4

Fourteen points in a row alternating up and down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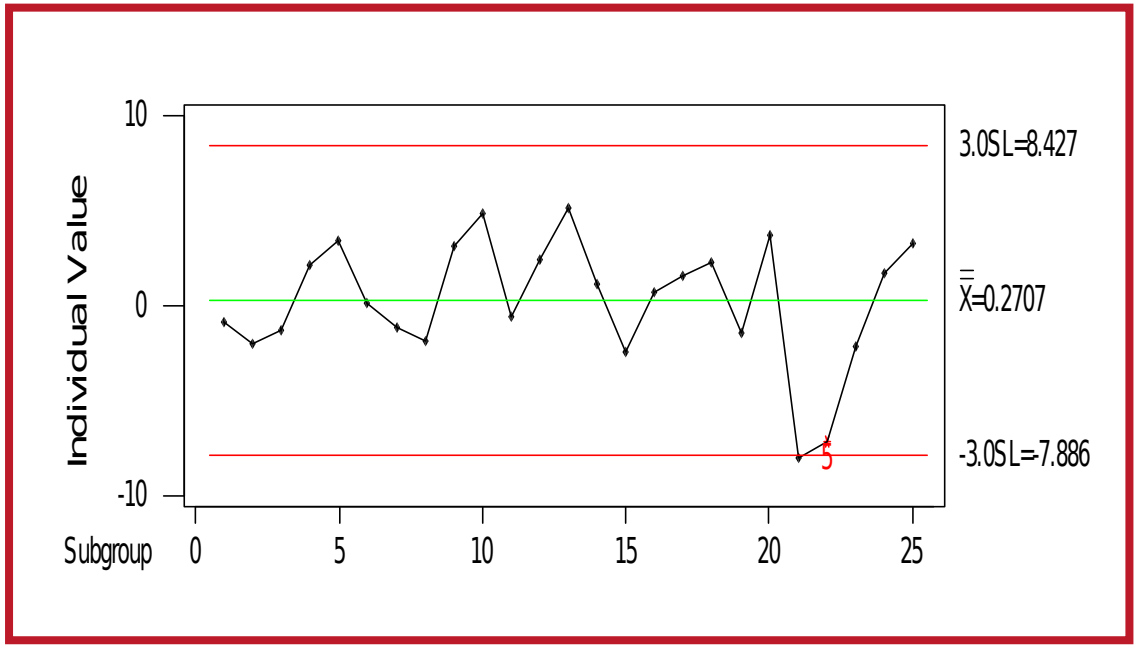
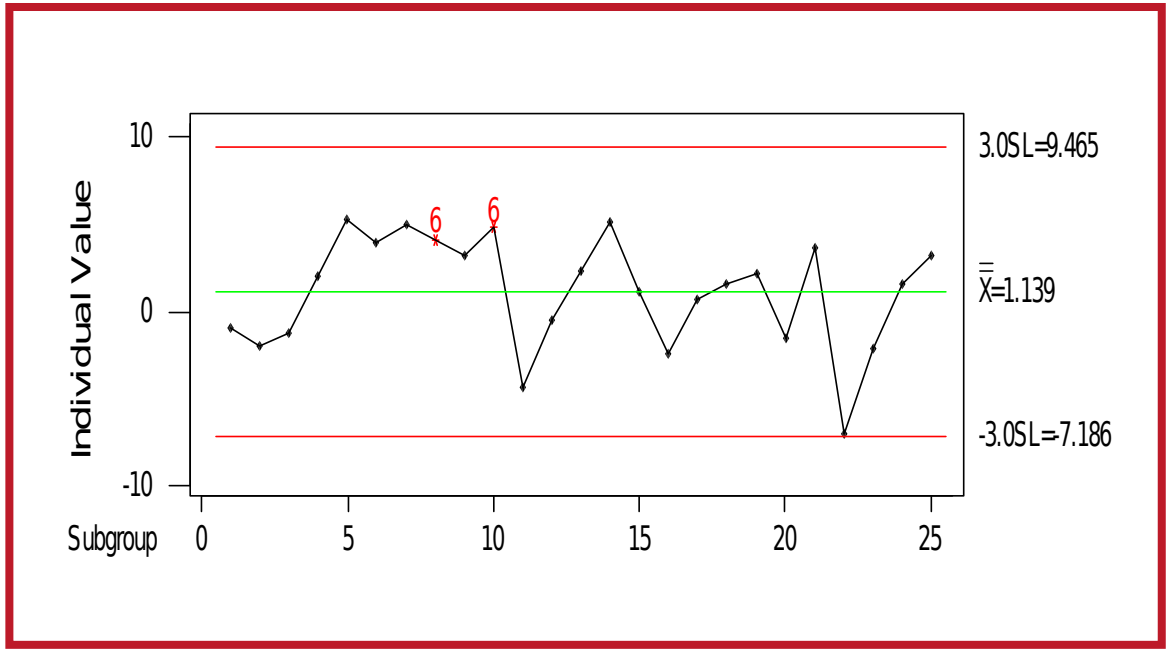
# Special Cause - Rules




Rule 5

Two out of three points more than 2ss from centerline (same side)




Rule 6

Four out of five points more than 1s from centerline (same side)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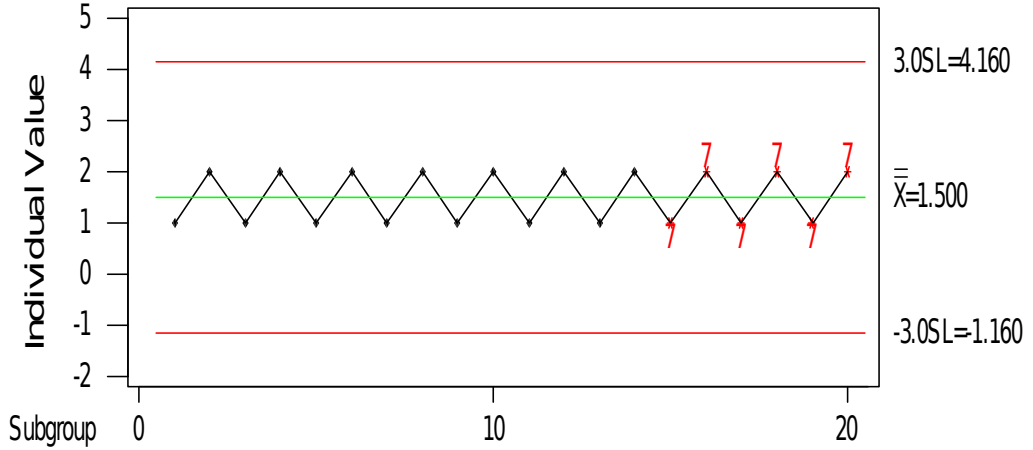
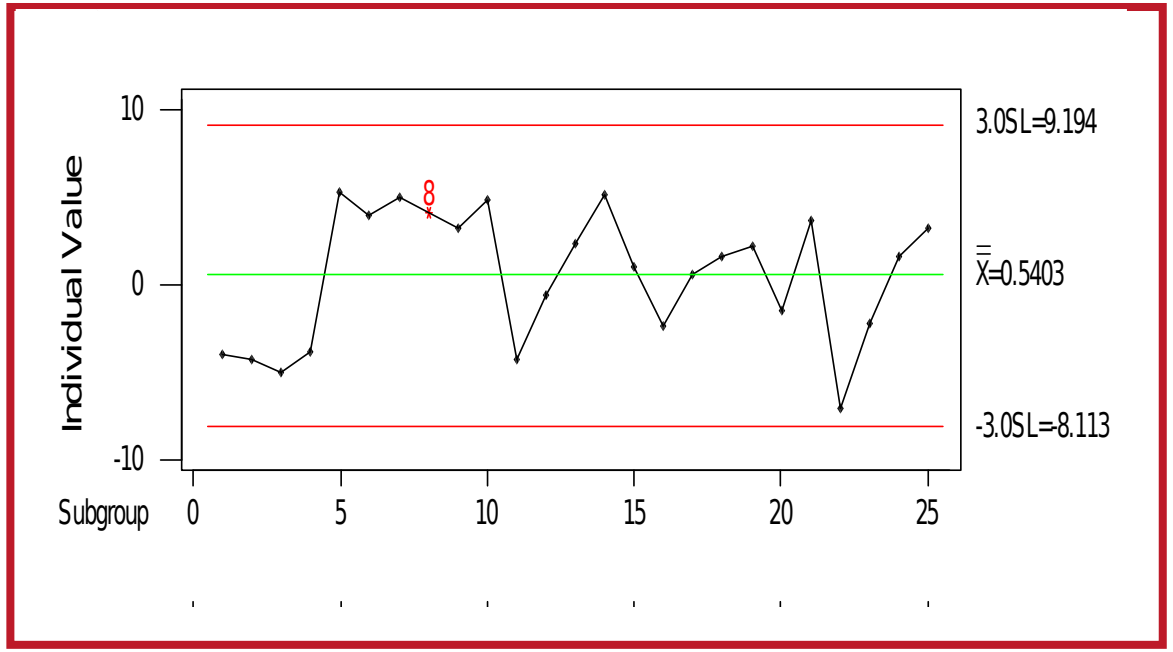
# Special Cause - Rules




Rule 7

Fifteen points in a row with in 1s from centerline (either side)




Rule 8

Eight points in a row more than 1s from centerline (either side)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# Decision Errors in SPC

Two Types of Errors possible in control charts

Calling a common cause of variation a special cause of variation  (Interfering with a stable process, wasting resources looking for special causes of variation that do not exist)

Calling a special cause of variation a common cause of variation (Missing a chance to identify a change in the process)


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# Key Concepts - SPC

Statistical Process Control is an excellent *upstream* process control tool. Control charts are ideally suited for monitoring and controlling your *"Vital Few" X variables*.

SPC for *continuous* variables is used to steer a process *towards a target*. Attribute SPC charts are used to *minimize defects*.

Control charts monitor the process variation and generate a signal when the process variation is influenced by *special cause variation*.

Requires an *appropriate response* to an "out-of-control" condition.

The sensitivity of a control chart to detect non-random variation can be improved by *increasing the subgroup sample size*.

Permanent control limits require at least *25 subgroups of data points that are "in-control"*.


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# Selecting What to Document

Activities critical to customer satisfaction

Processes/tasks that involve many people

- - Especially changing team players, multiple functions

Complex activities

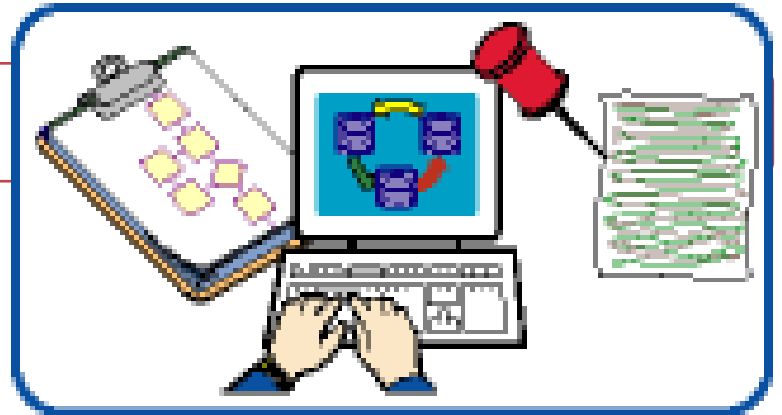
Areas where “history” is important

- - Will we need to refer to what we’ve done or how we did this later? (Examples: DMAIC project tracking and documentation)

Legal, audit requirements

- - Examples: Hiring process; financial procedures

Where flexibility is essential

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# Control Plan Sample Format

| Process | Measurement Method | Responsible | Sample Size | Frequency | Barrier to success | ANDON Cord | Rectification Plan | Follow Ups | Responsible-Follow Ups |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |


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